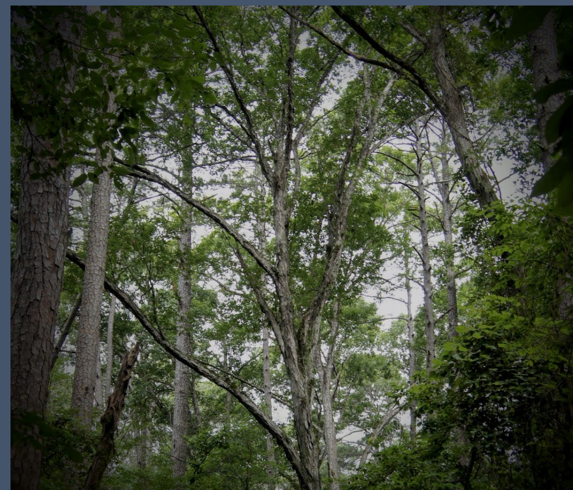

White Oak Regeneration Spatial Analysis – Final Report

Prepared in support of the White Oak Inititative Conservation Plan

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Cover Photo: 'White oak reaching for the pines'; by: Lance A. Vickers
Crossett Experimental Forest, Arkansas Alluvial Plains Ecological Section [234E]

EXECUTIVE SUMMARY

We collate and report analyses of USDA Forest Service Forest Inventory and Analysis data to assist the White Oak Initiative identify priority areas for conservation, restoration, and protection of white and upland oaks across twenty states that cover upland and white oak habitat. The twenty-state region includes: Minnesota, Wisconsin, Michigan, Iowa, Illinois, Indiana, Ohio, Pennsylvania, Missouri, Kentucky, West Virginia, Maryland, Virginia, Arkansas, Tennessee, North Carolina, Alabama, Georgia, Mississippi, and South Carolina. We also included data and analyses from thirteen additional states: Maine, New Hampshire, Vermont, New York, New Jersey, Massachusetts, Connecticut, Delaware, Rhode Island, Florida, Louisiana, Oklahoma, and Kansas. Combined, the 33-state region nearly spans the North American white oak range (**Figure 1**).

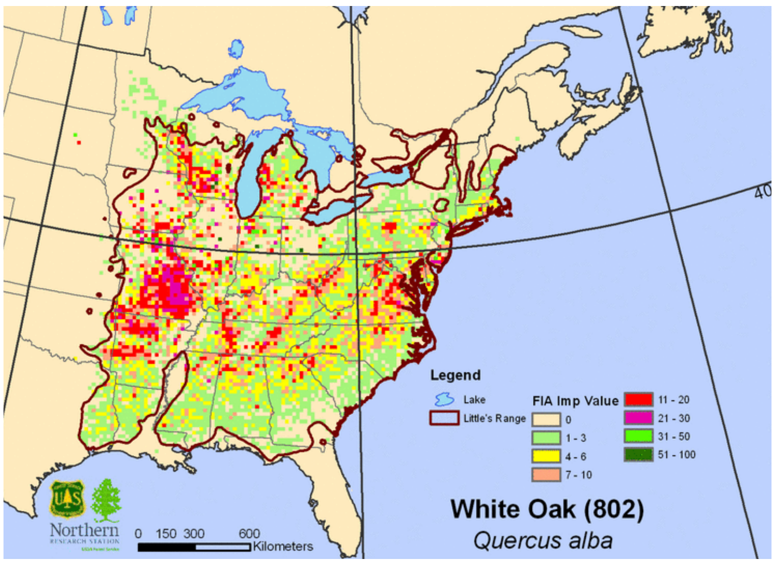


Figure 1. White oak (Quercus alba) range and prevalence[1].

The data used represent forest conditions circa 2017, the most recent inventory data available across the entire region. Most attributes are summarized by ecological sections, which are well-documented geographical delineations based on physical and biological components, are generally smaller and more homogenous than (most) states, and are but one tier in a comprehensive, hierarchical ecological classification system often used for spatial analysis. Consequently, the maps, figures, and tables provided should assist identification of geographical areas that may benefit from on-the-ground white or upland oak management to enhance wildlife habitat, conservation objectives and support forest products industries. In several cases, visualizations at scales finer than an ecological section are provided to offer further geographic insight, but data summaries are not provided for the finer, local scale.

[1] From Prasad et al. (2007)

TASKS

The following six tasks were identified by all parties to guide the analysis:

1. Analysis of contemporary upland and white oak range and prevalence using FIA data, focusing on 20 WOI States listed above
2. Within (1), conduct regional analysis of:
    a. Current upland and white oak forest age/maturity distribution
    b. Identify plausible regeneration-eligible areas based on age/maturity in 2a
3. Within regeneration eligible areas (2b), analysis of current forest demographics including:
    a. Prevalence of upland and white oaks in the overstory
    b. Prevalence of upland and white oak in the midstory (saplings)
    c. Prevalence of upland and white oak in the understory (seedlings)
4. Evaluate prospects of successful regeneration and recruitment for a suite of objectives by:
    a. Comparing current midstory and understory conditions (3b and 3c) with overstory (3a)
    b. Comparing current midstory and understory conditions (3b and 3c) with WOI defined targets
5. Based on 4, analysis highlighting:
    a. Areas where regeneration and recruitment success are unlikely,
    b. Areas where success is uncertain and/or strongly management dependent,
    c. Areas where success is plausible
6. Analysis of factors that influence regeneration success, potentially including:
    a. Site productivity
    b. Overstory density/composition
    c. Deer browsing
    d. Land ownership
    e. Other disturbances types and/or frequencies
    f. (invasive plant species)

The following nine points were chosen as perhaps the most relevant highlights from the results that address the six aforementioned tasks. The remainder of the document details the methodology used to complete those tasks along with associated results and observations.

HIGHLIGHTS

- White oak is widespread, with a range > 104 million forestland acres, but reaches its highest concentrations (% acres present) in the Boston Mountains (M223A; 74.5%), Northern Cumberland Plateau (221H; 72.7%), Ozark Highlands (223A; 69.7%), and Central Appalachian Piedmont (231I; 66.5%) ecological sections.
- White oak forestland is largely mature, about 75% of all white oak acres can be classified ≥ 'mature,' and that proportion is almost 60% or greater in each of the 59 ecological sections analyzed.
- In mature stands, white oaks become increasingly prevalent as large trees, while seedling abundance is variable and saplings are scarce. In many places, the next generation of white oak in mature stands is <u>not</u> clearly established. An estimated 60% of mature white oak acres have <u>no</u> white oak seedlings present and about 87% have <u>no</u> white oak saplings present.
- No section is immune to regeneration concerns. For example, while the Ozark Highlands (223A) has the 2nd lowest proportion of mature white oak acres without seedlings ('only' 37%), saplings are overwhelmingly absent (81% of acres). This highlights that regeneration concerns can be different in kind, those where bottlenecks appear in seedling establishment vs those where bottlenecks appear during canopy recruitment.
- Limited canopy recruitment of saplings is a concern across the range, white oak saplings were absent on no fewer than 72% of mature white oak acres in any ecological section.
- Among the larger ecological sections (≥ 1 million mature acres), white oak establishment concerns were *relatively* higher (≳ 75% seedling-less acres) in the Driftless and Escarpment (222L), Gulf Coastal Plains and Flatwoods (232B), and Central Appalachians (M221A, B, D). In contrast, establishment concerns were *relatively* lower (≤ 50% seedling-less acres) in the Ozark Highlands (223A), Shawnee Hills (223D), Central Appalachian Piedmont (231I), Ouachita Mountains (M231A), and Northern Lower Peninsula (212H).
- While white oak sprouting can make up some deficit in seedlings and sapling populations in a regeneration event, not all stems will sprout. Moreover, saplings and small trees are more reliable sprouters than large-diameter trees. Therefore, sole reliance on stump sprouting as the regeneration source will result in a net loss of white oak in the next generation.
- Many of the potentially influential factors examined appear to contribute at least some to the variability in seedling abundance, but locale, physiography, forest type, and disturbance history appear to be among the more important variables. Generally, many of these factors often work in concert and collectively point to areas where site productivity is relatively lower and disturbance is relatively greater or more frequent as more likely to favor white oak seedling abundance. For example, pine-heavy canopies on drier sites.
- Even within an ecological section, seedling and sapling presence and abundance is often spatially variable, suggesting that stand-level drivers and adaptive silviculture will be important determinants of stand development and regeneration outcomes.

METHODS

GENERAL APPROACH

For this report, 'upland oaks' include white (*Quercus alba*), black (*Q. velutina*), northern red (*Q. rubra*), southern red (*Q. falcata*), scarlet (*Q. coccinea*), chestnut (*Q. montana*), chinkapin (*Q. muehlenbergii*), and post (*Q. stellata*) oaks. Usually, we present results for both white oak alone and all upland oaks combined. Note: upland oak results include white oak.

All analyses presented herein are based on publicly available forest inventory data obtained from the USDA Forest Service Forest Inventory and Analysis (FIA) program (USDA Forest Service 2020). More detail on FIA sampling and procedures follows in the 'data' section. Population and other attribute estimates were derived using the rFIA package (Stanke & Finley 2020) for R software (R Core Team 2019). All geospatial manipulations were conducted using the raster and sf packages (Hijmans 2020, Pebesma 2018) in R software.

Our analyses were conducted at one of two spatial scales: Ecological section or local. Ecological sections are well-documented geographical delineations based on evaluation and integration of physical and biological components including climate, physiography, lithology, soils, and potential natural communities (McNab et al., 2007). Ecological sections are but one tier in a comprehensive, hierarchical ecological classification system often used for spatial analysis, and are identified in the FIA database for each plot. Sections are generally smaller and more homogenous than (most) states. All visual depictions of ecological section boundaries herein were derived from public shapefiles (https://data.fs.usda.gov/geodata/edw) that were masked to only show land where canopy cover ≥ 10% in 2016 according to the National Land Cover Database (NLCD, https://data.fs.usda.gov/geodata/rastergateway).

Most local scale analyses were computed by collocating relevant FIA plots within cells of a grid imposed on lands where canopy cover ≥ 10% according to NLCD. The grid resolution was usually 9842 ft. (3000 meters) resolution grid and represents approximately 12,000 acres, which generally includes about 2 FIA plots under normal FIA sampling intensity. An exception was invasive species analysis which used a sparser grid resolution (approximately 48,000 acres) due to sampling differences discussed later. We used publicly available plot locations from the FIA database to collocate plots within an appropriate grid cell. We note that because of local scale sample size limitations, we include only visualizations for insights into potential trends that may occur at finer scales, not summary data.

DATA

We initially obtained forest inventory data for all US states with land area east of the 100th meridian west (except Texas, excluded for database inconsistencies) for 2017. This is an area slightly more extensive than the recognized native white oak range in the US to allow for possible range expansion. Upon preliminary data inspection, no major expansions were obvious and white oak was not observed in the states of North Dakota, South Dakota, or Nebraska (**Figure 2**).

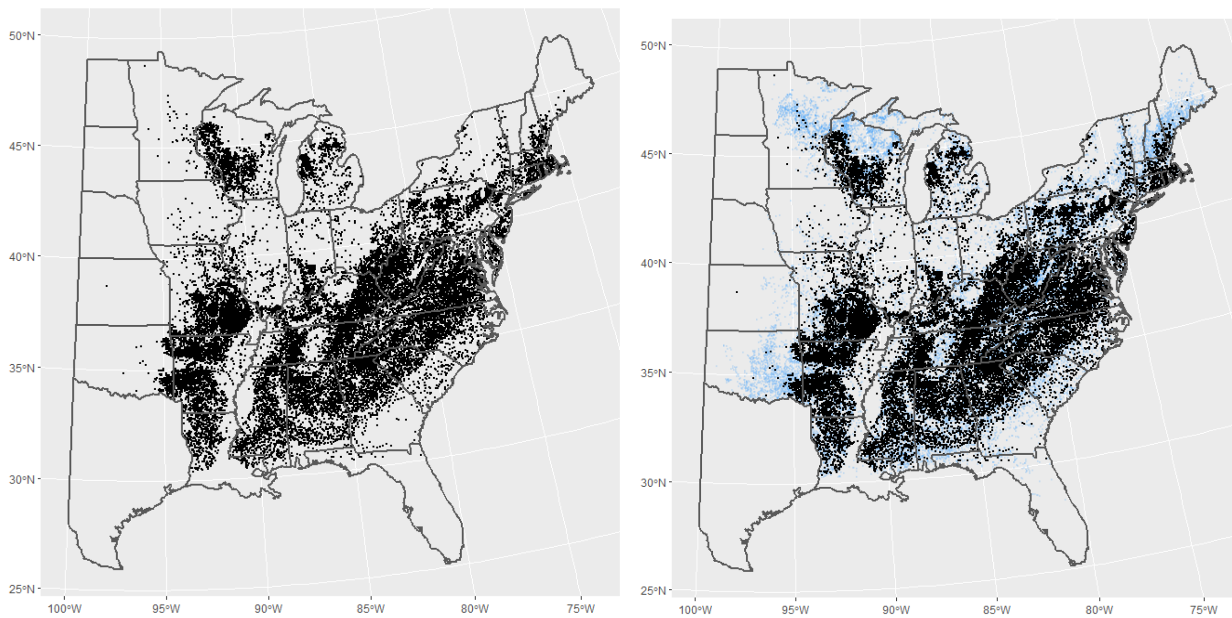


Figure 2. White and upland oak plot distribution, eastern US forestland, 2017. FIA plots with white oak present [L, black], and white or other upland oak present [R, blue].

At the time of data acquisition complete datasets were available for 2017 across all 33 states in the study region (USDA Forest Service 2020). The FIA national inventory is a uniform grid of sample locations, each representing approximately 6000 acres, though some states and ownerships have sampled at higher intensities. Inventories are conducted on 'forestland', which is defined as areas of at least 1 acre and no less than 120 ft wide with ≥ 10% canopy cover by trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated (see Bechtold and Patterson 2005). Tree-covered areas in agricultural production settings, such as fruit orchards, or tree covered areas in urban settings, such as city parks, are not forestland. Inventories are collected using a 'plot' (**Figure 3**) that occupies 1-acre and is composed of four circular subplots (24 ft. radius), each containing a circular microplot (6.8 ft. radius). Several tree attributes, including species, status (live or dead), cause of death (e.g., harvesting), and diameter at breast height ('dbh', 4.5 ft.), are collected at each location. Attributes of trees with dbh ≥ 5 in. are measured on subplots, whereas trees with a dbh 1-5 in. are measured on microplots. Seedlings (dbh < 1 in.), which include hardwoods with a height ≥ 12 in. and softwoods ≥ 6 in. are tallied on the same microplots. In addition to various tree-centric measures, inventories record several site attributes such as ownership group, forest type, stand size/maturity, and more ancillary site attributes to help describe the condition (USDA Forest Service 2019).

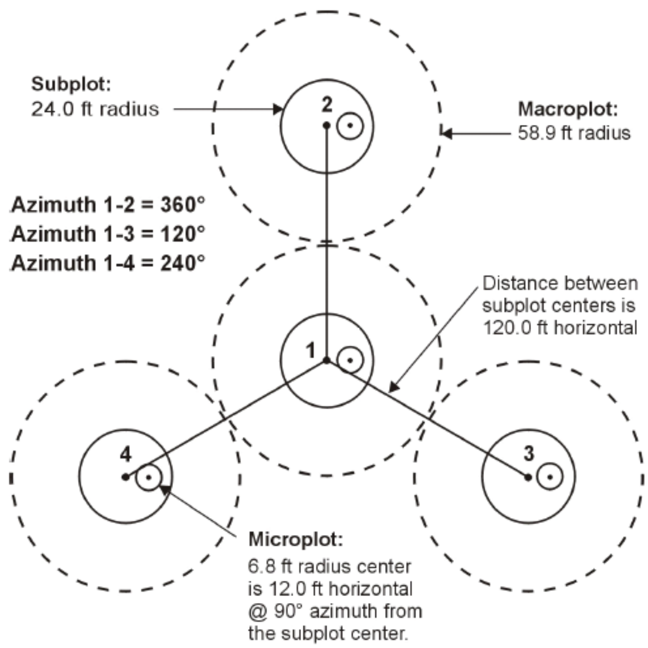


Figure 3. FIA plot design[1]. Note the 'macroplots' depicted in this figure are optional and unused in the region of interest for this analysis.

The annualized forest inventory sampling scheme currently used by FIA was adopted by most eastern states sometime between 1999-2004, varying by state (Burrill et al. 2018). Under the annualized inventory, a subset of FIA plots is measured every year so that all plots within a state are measured over a 5-7-year period, and thus each plot is remeasured every 5-7 years (Bechtold and Patterson 2005). Under this sampling schedule, FIA identifies evaluation datasets (EVALID codes) that can be used to select the most recent complete set of statewide measurements relevant to various attributes of interest in a given year (Bechtold and Patterson 2005, Pugh et al. 2018). In Missouri, for example, a current area evaluation dataset for 2017 included all plots measured from 2011-2017.

[1] From Burrill et al. 2018

TASK-SPECIFIC METHODS

TASK 1: CONTEMPORARY RANGE AND PREVALENCE

In this document we refer to 'white oak forestland' as forestland where at least one white oak tree of any size is present (i.e., FIA plots where white oak was recorded). Similarly, we refer to forestland where any size or species of upland oak (including white oak) is present as 'upland oak forestland.' By definition, white oak forestland is a subset of upland oak forestland.

We assume that upland oak forestland is generally suited for white oaks for several reasons: 1) white oak has a broad range and relatively broad silvical requirements; 2) there is general overlap in silvics among white oak and the other upland oaks under consideration (Burns & Honkala 1990); 3) there are inherent limitations of a plot to comprehensively capture forest conditions; and 4) to simplify comparison and interpretation. We further assume that white oak could occupy plots where other upland oaks are present. Thus, unless otherwise explicitly stated, any area-ratio tree estimates (e.g., trees per acre) use upland oak forestland as the area denominator. Recognizing that this assumption is probably weakest in those areas near the white oak range boundaries, to alleviate concern we only used inventory data from those ecological sections with ≥ 75,000 acres of white oak forestland. There were 59 ecological sections that met this criterion and for the purposes of our analyses those sections represent the white oak 'range' that was used for task 1 and subsequent analyses (**Figure 4**).

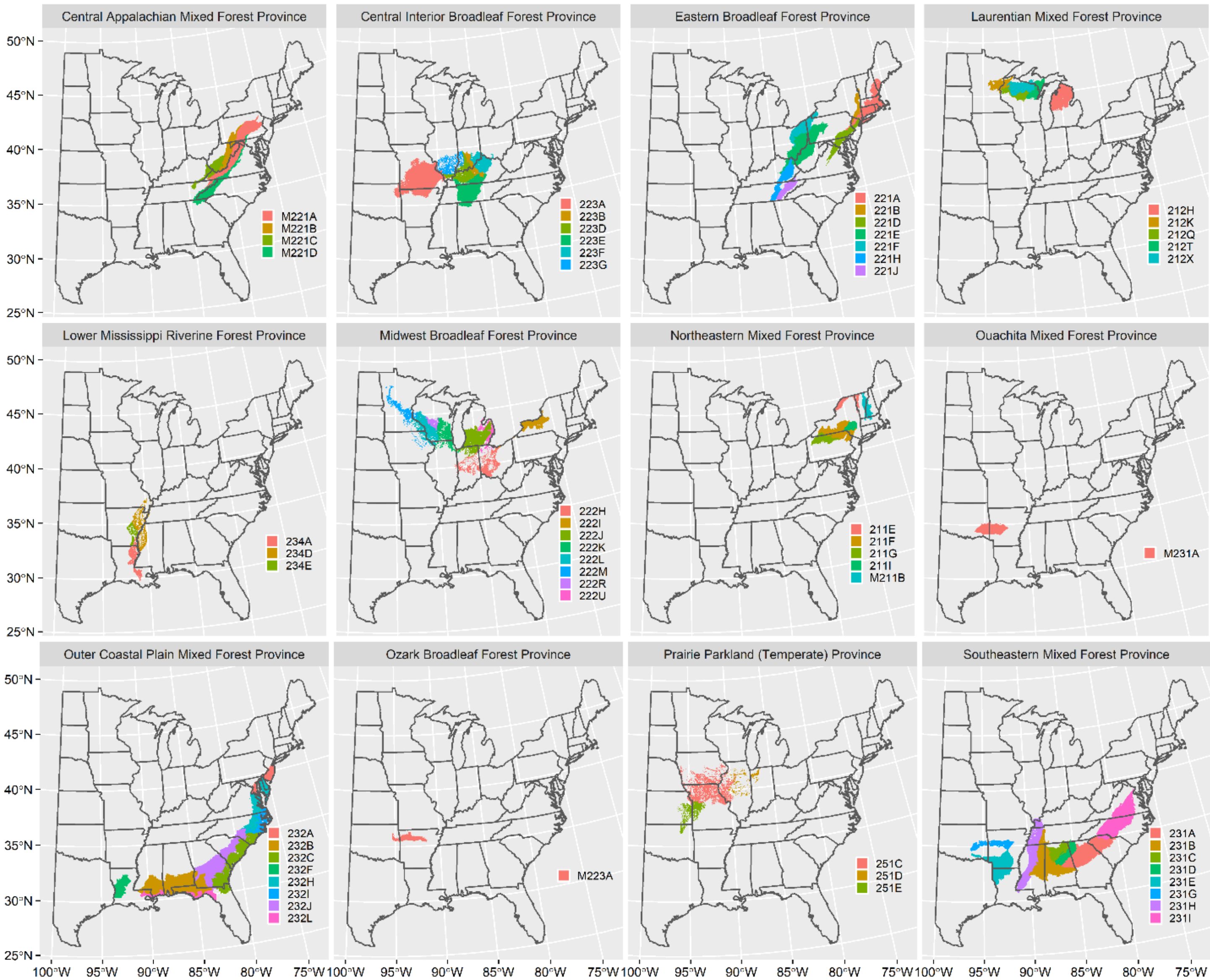


Figure 4. Ecological sections used to analyze upland oaks, eastern US forestland, 2017. All sections had at least 75,000 acres of forestland with white oak present. Panels depict ecological sections within the same province, a higher level classification. Corresponding section names can be found in Table 1, e.g., section M221A = Northern Ridge and Valley.

TASK 2: AGE/MATURITY DISTRIBUTION, REGENERATION ELIGIBLE AREAS

To analyze forest age/maturity forestland is categorized into one of four stand structural stages, used as a proxy for age as many forests in the eastern US have tree species that differ drastically in growth strategies and have experienced extensive disturbance histories making nominal forest age difficult to obtain and interpret. The four structural stages are categorized according to basal area and diameter distributions present on a plot (see https://rdrr.io/cran/rFIA/man/standStruct.html) and include 'late', 'mature', 'pole', and 'mosaic' and generally follow an age pattern where late > mature > pole > mosaic. Formally,

- **Late stage** plots have ≥ 67% of their basal area in mature and large diameter classes (dbh: 10-17 in., and ≥ 18 in., respectively), but more basal area in the large class.
- **Mature stage** plots have ≥ 67% of their basal area in mature and large diameter classes with more basal area in the mature class, *or*,
  - ≥ 67% of their basal area in mature and pole diameter classes (dbh: 4-9 in.) but more basal area in the mature class.
- **Pole stage** plots have ≥ 67% of their basal area in mature and pole diameter classes but more basal area in the pole class.
- Finally, any plot not meeting the other criteria is categorized as **mosaic**.

We defined 'regeneration eligible' areas, i.e., stands that are or will soon be mature enough for a forester to begin contemplating regeneration, as plots in the 'mature' and 'late' stages. Age estimates for regeneration eligible areas vary but are generally ≥ 65 years (Figure 5).

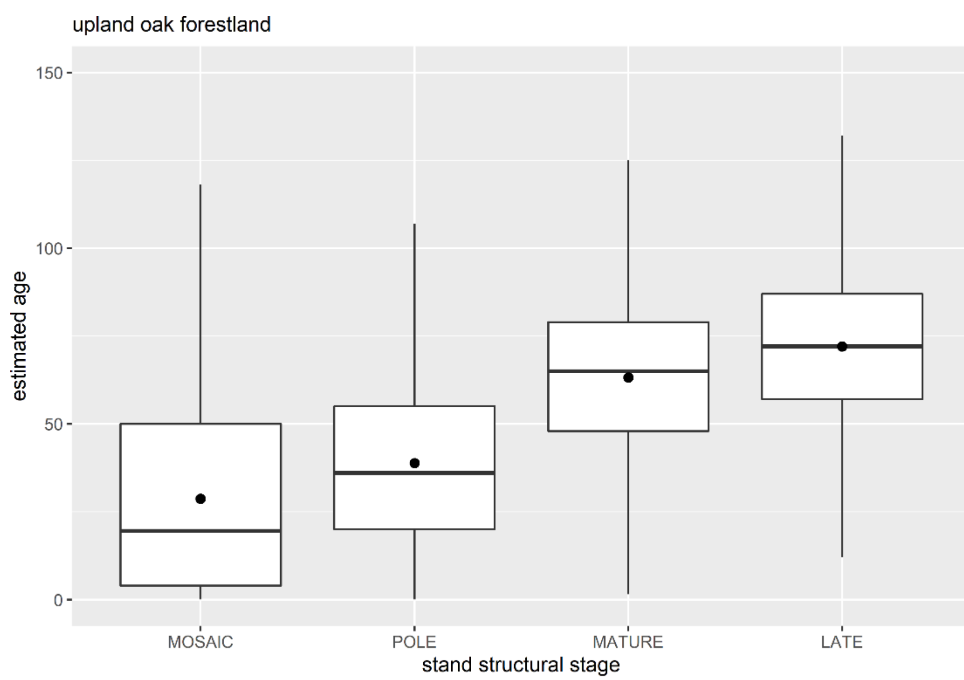


Figure 5. Upland oak structrual stage-age relationship , eastern US upland oak forestland, 2017.

TASK 3: SUMMARIZE CANOPY, SAPLING, AND SEEDLING POPULATION OF REGENERATION ELIGIBLE AREAS

All regeneration-based analyses (i.e., tasks 3-6) were based on data from regeneration eligible forestland. Canopy positions are defined by FIA as follows (Burrill et al. 2018):

- **Dominant** trees have crowns extending above the general level of the canopy and receive full light from above and partly from the sides; are larger than the average trees in the stand, and with crowns well developed, but possibly somewhat crowded on the sides.
- **Codominant** trees have crowns forming part of the general level of the canopy cover and receive full light from above, but comparatively little from the side. Two other crown classes were not considered part of the canopy: intermediate and overtopped.
- **Intermediate** trees are shorter than those in the preceding two classes, with crowns either below or extending into the canopy formed by the dominant and codominant trees and receive little direct light from above, and none from the sides.
- **Overtopped** trees have crowns entirely below the general canopy level and receive no direct light either from above or the sides.

Summaries of 'upper canopy' populations for tasks 3-4 include only those trees in dominant or codominant crown classes. We defined the 'sapling' population as trees with a dbh 1-3 in, which will generally be in an overtopped crown class in regeneration eligible forests, though that was not an explicit requirement. Seedlings (dbh < 1 in.) include hardwoods (all oaks) with a height ≥ 12 in. and softwoods ≥ 6 in. Potential sprouts are an estimate of which oak stems with a dbh ≥ 3 in. are likely to reproduce via stump sprouting (coppice) if harvested. The sprouting probability for a given tree was estimated from equations used by the Forest Vegetation Simulator, Southern Variant and is a function of upland oak species and diameter (Keyser 2008).

Growing space occupancy was quantified using Gingrich stocking (Gingrich 1967), a measure of site occupancy developed in upland oak forests that considers both the number and size distribution of trees. Gingrich stocking is scaled such that a value of approximately 60(%) represents full stand occupancy, i.e., crown closure, and a value ≥ 100(%) suggests overstocking and competition induced mortality, which often begins at a stocking value around 80(%) stocking, will be ubiquitous.

TASK 4: COMPARE MID- AND UNDERSTORY POPULATION TO CANOPY OF REGENERATION ELIGIBLE AREAS

The mid- and understory populations are compared to the canopy via abundance and relative abundance of white and upland oaks in total and by diameter class and canopy position.

TASK 5: HIGHLIGHT AREAS OF REGENERATION CONCERN

Regeneration eligible acreage with species of interest present as trees but not as reproduction (seedlings or saplings) is the primary metric used to highlight areas of regeneration concern. Both total acreage and proportional acreage without reproduction is examined by the type of reproduction (seedlings or saplings), and species of interest (white or upland oaks).

TASK 6: INVESTIGATE EFFECTS OF PLAUSIBLY INFLUENTIAL FACTORS

SITE PRODUCTIVITY

While site index is probably the most familiar site productivity metric and of great utility, there are inherent challenges in its application in broad scale analyses, including obtaining tree ages, accounting for species growth patterns, as well as assumptions about stand development and disturbance histories. Our analysis of the potential influence of site productivity on upland oak seedling abundance on regeneration eligible upland oak forestland was based on two variables within the FIA database (Burrill et al. 2018): site productivity class (SITECLCD), and physiographic class code (PHYSCLCD). Site productivity class is a classification of forest land in terms of inherent capacity to grow crops of industrial wood. This variable identifies the potential growth in cubic feet/acre/year and is based on the culmination of mean annual increment of fully stocked natural stands. These seven site productivity classes show a correlation with white oak site index estimates when such data is available and approximately correspond with white oak site index values of 35, 55, 65, 70, 80, 100, and 110 ft. at a base age of 50. Physiographic classes attempt to capture the general effect of land form, topographical position, and soil on moisture available to trees.

OVERSTORY DENSITY/COMPOSITION

Our analysis of the potential influence of overstory density and composition on upland oak seedling abundance was based on two variables within the FIA database (Burrill et al. 2018): stocking class (ALSTKCD), and forest type code (FORTYPCD).

DEER BROWSING

Our analysis of the potential influence of deer density on upland oak seedling abundance was based on categorical estimates of deer density per square mile from the widest-ranging, publicly-available, and single-source data known to us (Walters et al. 2016). These estimates cover from Minnesota south to Louisiana and all states eastward. The estimates are based on data collected from 2001-2005, and while somewhat dated, we note that the 2017 FIA data used included measurements from the preceding 5-7 years and that many of the inventoried upland oak seedlings, which were ≥ 12 in. tall, probably germinated even earlier.

LAND OWNERSHIP

Our analysis of the potential influence of land ownership on upland oak seedling abundance was based on the ownership group code (OWNGRPCD) within the FIA database (Burrill et al. 2018): which differentiates between Forest Service land, other federal land, state or local government land, and private or Native American lands.

OTHER DISTURBANCES

Our analysis of the potential influence of other disturbance types was based on the primary disturbance code (DSTRBCD1) within the FIA database (Burrill et al. 2018). This code indicates the kind of disturbance occurring since the last measurement or within the last 5 years for new plots. The area affected by the disturbance must be at least 1 acre in size. A significant level of disturbance (mortality or damage to 25 percent of the trees in the condition) is required to qualify as a disturbance.

INVASIVE SPECIES

Our analysis of the potential influence of invasive species was limited to identifying the most common invasive species on upland oak forestland using FIA invasive species data. Each FIA unit, in collaboration with vegetation experts, has developed lists of the most important invasive species to monitor on forested lands. Canopy cover is estimated for any listed invasive species present on a subplot, regardless of abundance (i.e., there is not minimum cover threshold for sampling). Only listed species rooted in or overhanging (and rooted out of) this condition are included. For tree species, there are no minimum (or maximum) height limits as are required for seedling counts. In the northern US (bounded by North Dakota south to Kansas and eastward from Maine to Maryland), a list of 44 invasive plants are currently (since 2012) inventoried on 12.5% of plots (roughly one per 48,000 acres). In the southern US (bounded by Arkansas south to Louisiana and eastward from Virginia to Florida, plus Oklahoma), at least 49 invasive plants are currently inventoried on all plots. We provide common names for any invasive species mentioned and follow naming conventions in the USDA NRCS PLANTS Database (https://plants.sc.egov.usda.gov/java/).

RESULTS

TASK 1: CONTEMPORARY RANGE AND PREVALENCE

White oak (Quercus alba) is a widespread upland oak with a range spanning much of the eastern US and parts of Canada (**Figure 1**). Within the eastern US (eastward of 100° W [excluding TX]), forest inventory estimates white oak presence on about 104 million of the estimated 311 million acres of forestland (**Figure 6**). About 187 million acres in the eastern US were estimated to have at least one upland oak species present (**Table 1**).

Ecological sections where forestland acres with white oak present exceed 5 million include the Ozark Highlands (223A; 10.92 million acres), Central Appalachian Piedmont (231I; 8.18 million acres), Southern Appalachian Piedmont (231A; 6.33 million acres), Southern Unglaciated Allegheny Plateau (221E; 6.2 million acres) and the Coastal Plains-Middle (231B; 5.16 million acres).

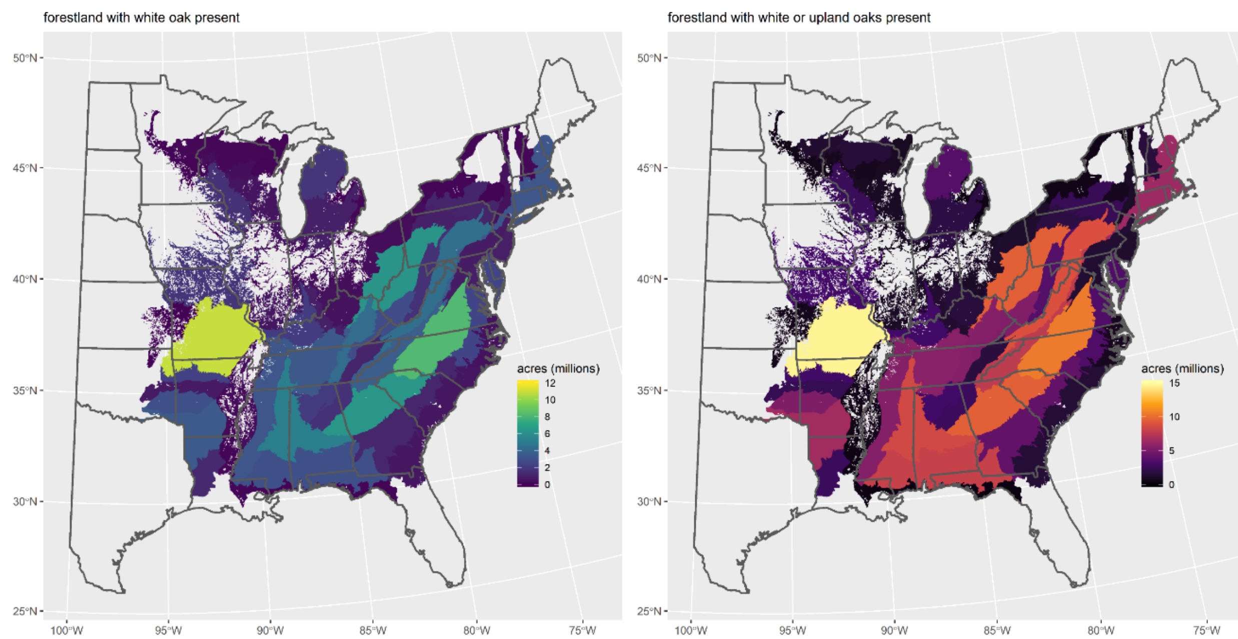


Figure 6. White and upland oak forestland by ecological section, millions of acres, white oak present [L], or any upland oaks present [R], eastern US forestland, 2017.

There are eleven ecological sections where the proportion of white oak forestland exceeded 50% and is at least two-thirds in the Boston Mountains (M223A; 74.5%), Northern Cumberland Plateau (221H; 72.7%), Ozark Highlands (223A; 69.7%), and Central Appalachian Piedmont (231I; 66.5%) sections (Figure 7).

A total of 15 ecological sections have upland oaks present on at least 5 million acres and the proportion of upland oak forestland exceeded 50% in 35 of the 59 ecological sections under consideration. Upland oaks are present on at least 90% of the forestland acres in the Boston Mountains (M223A; 96.8%), Ozark Highlands (223A; 93.3%), Northern Cumberland Plateau (221H; 92%), and Ouachita Mountains (M231A; 90.7%) sections.

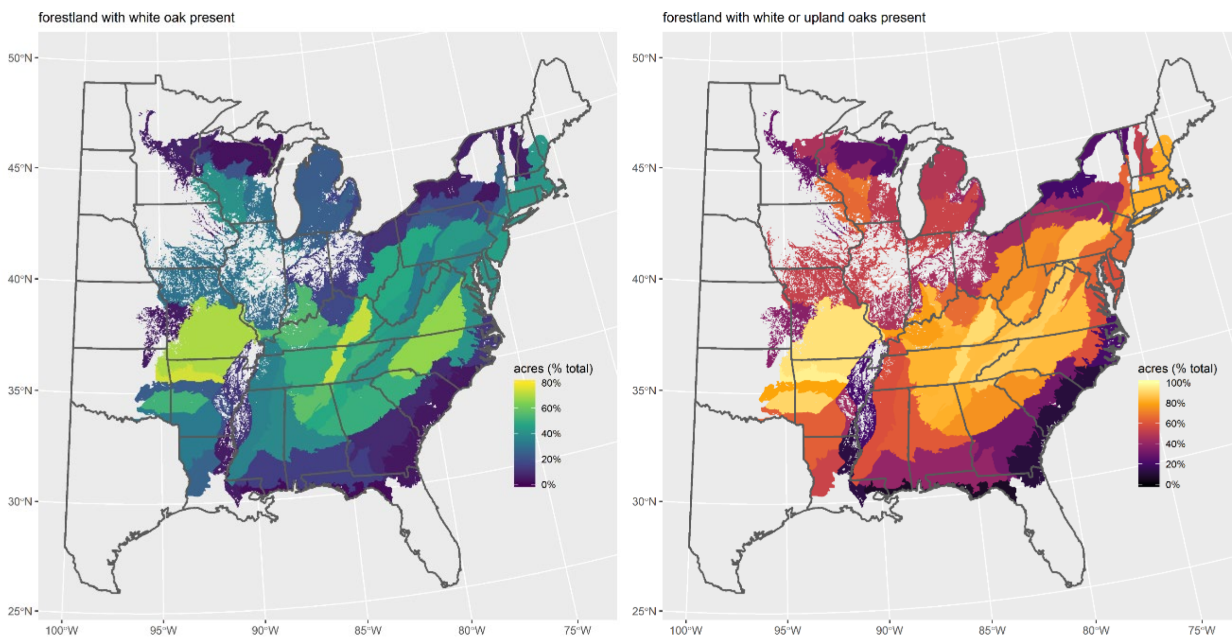


Figure 7. White and upland oak forestland proportion by ecological section, white oak present [L], or any upland oaks present [R] by ecological section, eastern US forestland, 2017.

Table 1. White and upland oak forestland area by ecological section, eastern US forestland, 2017.

		Forestland			Proportion	
SCT_CD	Section Name	Total	Upland oak	White oak	Upland oak	White oak
		… acres (millions) …			… % total …	
211E	St. Lawrence and Champlain Valley	1.82	0.43	0.12	23.4%	6.5%
211F	Northern Glaciated Allegheny Plateau	6.18	2.47	1.12	40.0%	18.2%
211G	Northern Unglaciated Allegheny Plateau	3.97	1.90	0.91	47.9%	23.0%
211I	Catskill Mountains	1.86	0.71	0.08	38.4%	4.0%
212H	Northern Lower Peninsula	7.53	3.66	1.78	48.7%	23.6%
212K	Western Superior Uplands	2.86	1.32	0.19	46.2%	6.8%
212Q	North Central Wisconsin Uplands	1.50	0.68	0.32	45.3%	21.1%
212T	Northern Green Bay Lobe	3.39	0.80	0.10	23.7%	2.9%
212X	Northern Highlands	5.78	1.56	0.17	27.1%	2.9%
221A	Lower New England	7.69	6.33	3.23	82.3%	42.0%
221B	Hudson Valley	1.58	1.01	0.41	64.1%	25.9%
221D	Northern Appalachian Piedmont	2.07	1.36	0.76	65.7%	36.5%
221E	Southern Unglaciated Allegheny Plateau	12.83	9.48	6.20	73.9%	48.3%
221F	Western Glaciated Allegheny Plateau	2.72	1.19	0.31	43.8%	11.5%
221H	Northern Cumberland Plateau	5.86	5.39	4.26	92.0%	72.7%
221J	Central Ridge and Valley	2.07	1.76	1.06	85.1%	51.4%
222H	Central Till Plains-Beech-Maple	2.20	0.98	0.30	44.6%	13.8%
222I	Erie and Ontario Lake Plain	2.29	0.46	0.12	20.1%	5.3%
222J	South Central Great Lakes	3.57	1.94	0.88	54.2%	24.6%
222K	Southwestern Great Lakes Morainal	1.76	0.90	0.53	51.1%	30.0%
222L	North Central U.S. Driftless and Escarpment	3.92	2.55	1.58	65.0%	40.3%
222M	Minnesota and Northeast Iowa Morainal-Oak Savannah	1.73	0.50	0.10	28.8%	5.6%
222R	Wisconsin Central Sands	1.24	0.85	0.49	68.8%	39.3%
222U	Lake Whittlesey Glaciolacustrine Plain	0.91	0.38	0.15	41.8%	16.6%
223A	Ozark Highlands	15.68	14.63	10.92	93.3%	69.7%
223B	Interior Low Plateau-Transition Hills	1.58	1.33	0.86	84.5%	54.2%
223D	Interior Low Plateau-Shawnee Hills	3.75	2.94	2.07	78.3%	55.0%
223E	Interior Low Plateau-Highland Rim	6.68	5.56	3.35	83.2%	50.2%
223F	Interior Low Plateau-Bluegrass	2.60	1.71	0.45	65.8%	17.5%
223G	Central Till Plains-Oak Hickory	2.05	0.95	0.58	46.5%	28.2%

		Forestland			Proportion	
SCT_CD	Section Name	Total	Upland oak	White oak	Upland oak	White oak
		… acres (millions) …			… % total …	
231A	Southern Appalachian Piedmont	12.59	9.48	6.33	75.3%	50.3%
231B	Coastal Plains-Middle	13.69	8.46	5.16	61.8%	37.7%
231C	Southern Cumberland Plateau	3.52	2.95	2.01	84.0%	57.1%
231D	Southern Ridge and Valley	3.21	2.65	1.55	82.3%	48.3%
231E	Mid Coastal Plains-Western	10.39	6.54	3.42	62.9%	32.9%
231G	Arkansas Valley	2.95	2.36	0.71	80.0%	24.0%
231H	Coastal Plains-Loess	9.11	5.39	3.20	59.2%	35.2%
231I	Central Appalachian Piedmont	12.31	10.44	8.18	84.8%	66.5%
232A	Northern Atlantic Coastal Plain	1.91	1.21	0.85	63.6%	44.7%
232B	Gulf Coastal Plains and Flatwoods	19.93	8.00	2.92	40.1%	14.7%
232C	Atlantic Coastal Flatwoods	13.53	1.51	0.57	11.2%	4.2%
232F	Coastal Plains and Flatwoods-Western Gulf	4.83	2.62	1.23	54.2%	25.5%
232H	Middle Atlantic Coastal Plains and Flatwoods	5.76	3.41	2.38	59.2%	41.4%
232I	Northern Atlantic Coastal Flatwoods	3.46	0.73	0.42	21.1%	12.2%
232J	Southern Atlantic Coastal Plains and Flatwoods	13.07	4.09	1.15	31.3%	8.8%
232L	Gulf Coastal Lowlands	4.72	0.30	0.09	6.3%	1.9%
234A	Southern Mississippi Alluvial Plain	2.74	0.34	0.14	12.6%	5.2%
234D	White and Black River Alluvial Plains	2.72	0.56	0.32	20.5%	11.8%
234E	Arkansas Alluvial Plains	1.12	0.48	0.22	43.1%	19.2%
251C	Central Dissected Till Plains	5.73	3.04	1.73	53.1%	30.1%
251D	Central Till Plains and Grand Prairies	0.78	0.43	0.27	55.2%	34.5%
251E	Osage Plains	1.62	0.60	0.08	37.0%	4.7%
M211B	New England Piedmont	3.26	1.70	0.19	52.0%	5.8%
M221A	Northern Ridge and Valley	10.05	8.85	4.38	88.1%	43.5%
M221B	Allegheny Mountains	5.06	3.61	1.61	71.2%	31.9%
M221C	Northern Cumberland Mountains	6.13	5.23	2.81	85.2%	45.8%
M221D	Blue Ridge Mountains	8.58	7.66	3.60	89.2%	41.9%
M223A	Boston Mountains	3.02	2.92	2.25	96.8%	74.5%
M231A	Ouachita Mountains	5.72	5.19	2.96	90.7%	51.7%
	TOTAL	311.17	186.48	104.12	60.0%	33.5%

TASK 2: AGE/MATURITY DISTRIBUTION, REGENERATION ELIGIBLE AREAS

White and upland oak forestland is largely mature or older (Figure 8). About 75% of all white oak acres are classified as 'regeneration eligible' (mature or late structural stage) and that proportion is almost 60% or greater in each of the 59 ecological sections under consideration (Figure 9). Conversely, < 3% is classified as young (mosaic) across the entire eastern US.

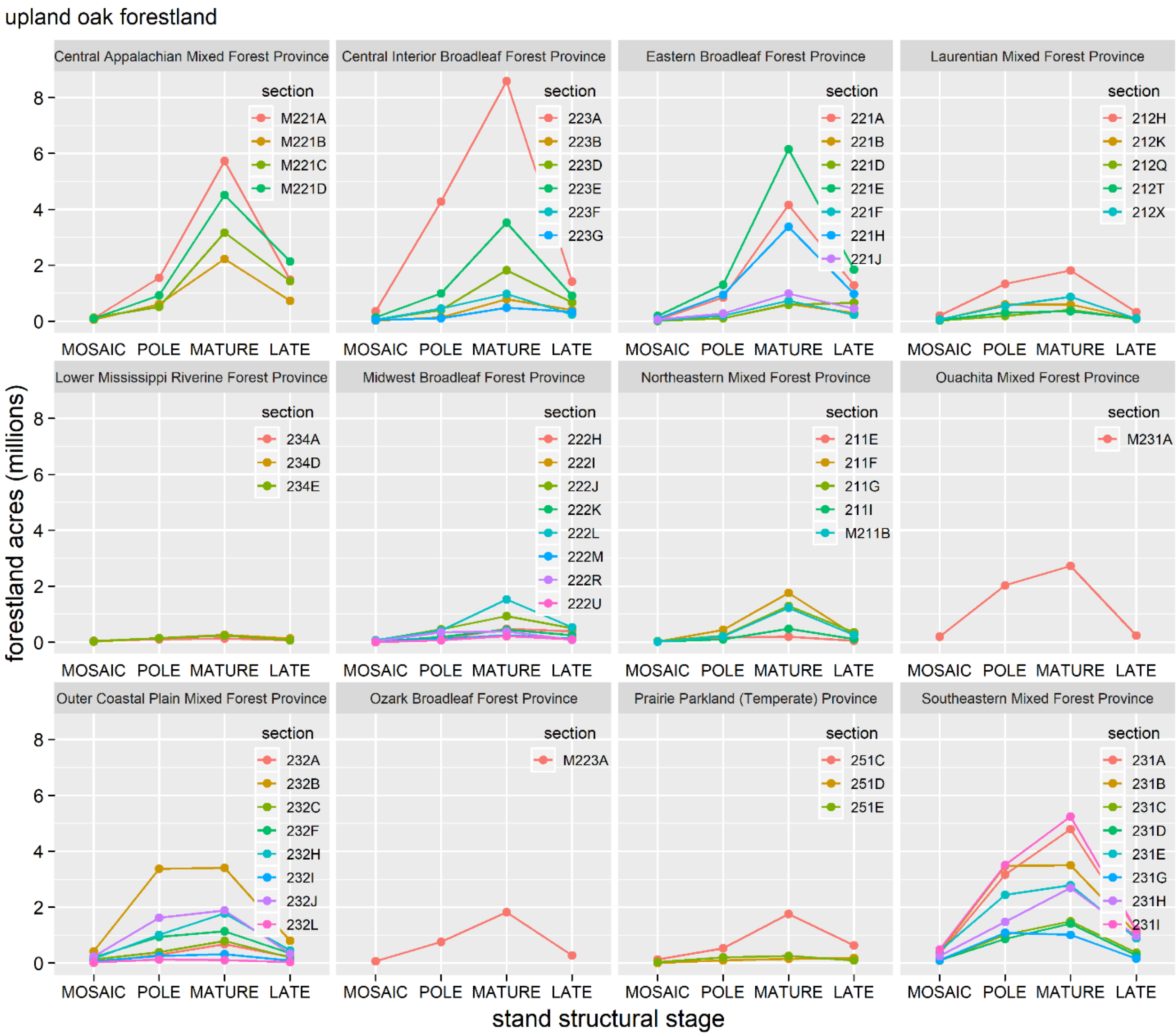


Figure 8. Upland oak forestland area by structural stage and ecological section, millions of acres, eastern US upland oak forestland, 2017. Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

Across the range, 24 ecological sections have ≥ 1 million regeneration eligible acres with white oak present, and the Ozark Highlands (223A; 8.0 million acres), Southern Unglaciated Allegheny Plateau (221E; 5.3 million acres), and Central Appalachian Piedmont (231I; 5.2 million acres) all exceed 5 million regeneration eligible acres (Table 2). Over 70% of upland oak forestland can be classified as regeneration eligible; at least 49% in each ecological section (Figure 10), while young forest was only about 3%. These age imbalances are not limited to oak forestland, about 65% of all forestland in the area under consideration is regeneration eligible and only about 5% young. Sections vary in the amount of mature forest but, young forest was low across all sections. Some sections, like Gulf Coastal Plains and Flatwoods [232B] and Coastal Plains-Middle [231B] had similar pole and mature proportions but that was uncommon overall.

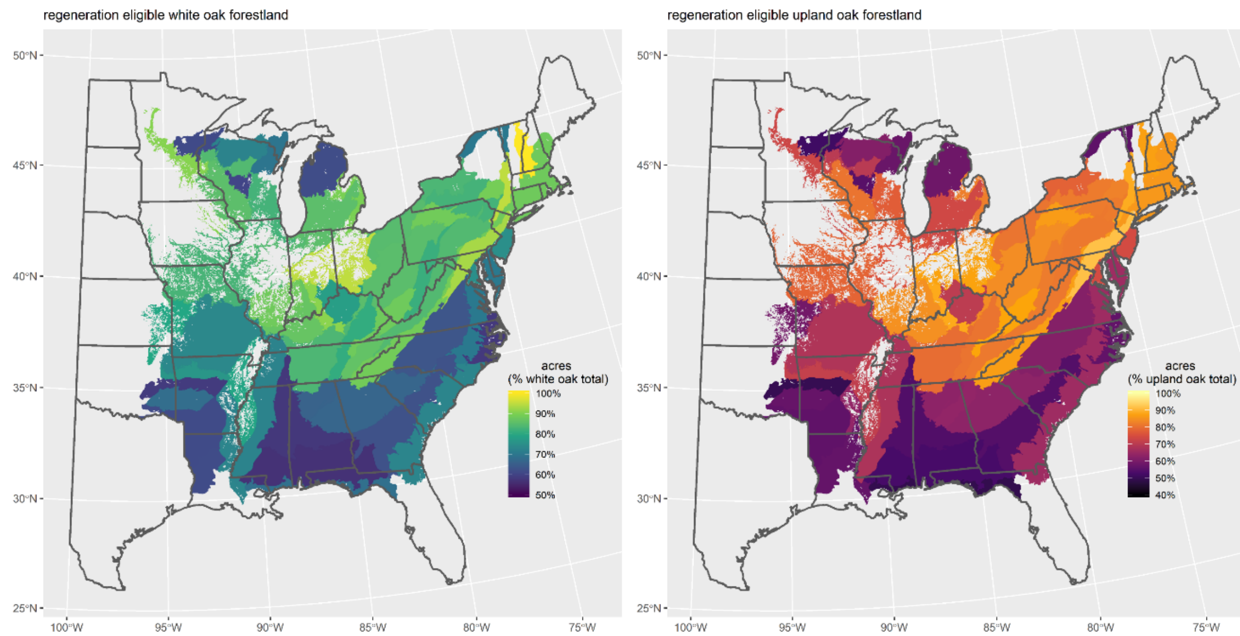


Figure 9. White and upland oak forestland regeneration eligible proportion by ecological section, white oak present [L] or any upland oak present [R]. Regeneration eligible includes forestland in mature or late structural stages (see Figure 5).

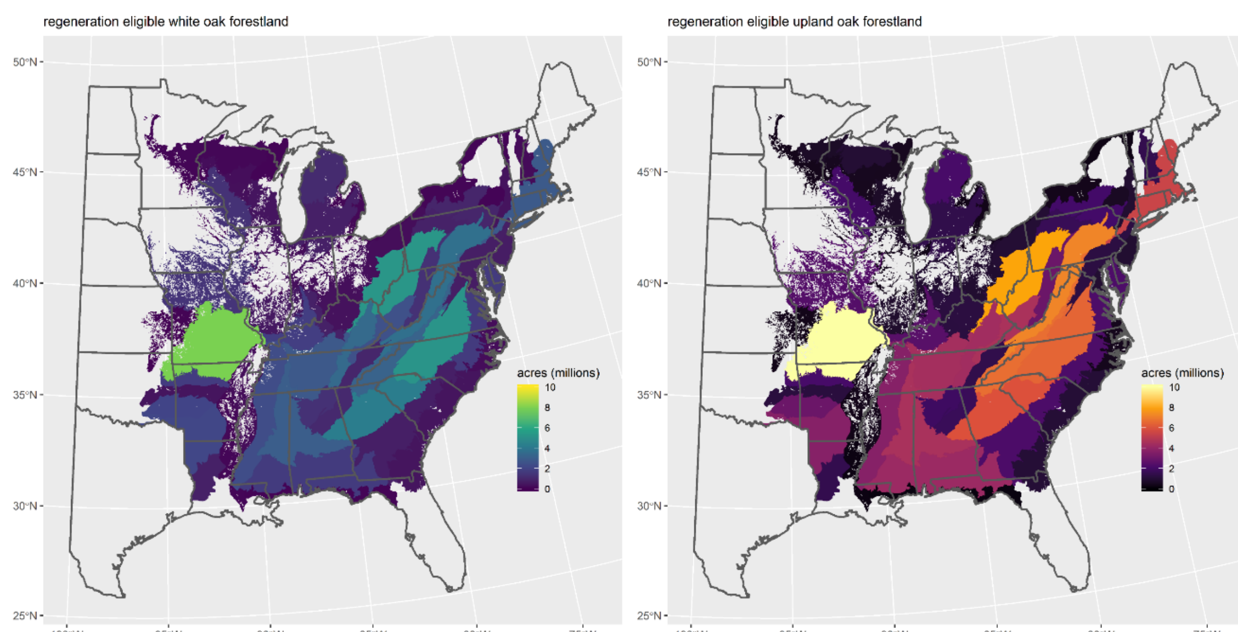


Figure 10. White and upland oak forestland regeneration eligible area, millions of acres, white oak [L] or any upland oak present [R], eastern US forestland, 2017.

Table 2. White and upland oak regeneration eligible forestland by ecological section, eastern US forestland, 2017.

		Regeneration eligible forestland			Proportion	
SCT_CD	Section Name	Total	Upland oak	White oak	Upland oak	White oak
		… acres (millions) …			… % species total …	
211E	St. Lawrence and Champlain Valley	0.90	0.24	0.08	56%	70%
211F	Northern Glaciated Allegheny Plateau	4.82	2.02	0.93	82%	83%
211G	Northern Unglaciated Allegheny Plateau	3.31	1.65	0.81	87%	88%
211I	Catskill Mountains	1.52	0.59	0.07	83%	89%
212H	Northern Lower Peninsula	4.01	2.13	1.10	58%	62%
212K	Western Superior Uplands	1.22	0.68	0.12	51%	61%
212Q	North Central Wisconsin Uplands	0.86	0.48	0.27	70%	84%
212T	Northern Green Bay Lobe	1.43	0.46	0.07	57%	69%
212X	Northern Highlands	2.80	0.96	0.12	61%	72%
221A	Lower New England	6.34	5.44	2.85	86%	88%
221B	Hudson Valley	1.30	0.90	0.39	89%	95%
221D	Northern Appalachian Piedmont	1.79	1.25	0.70	92%	93%
221E	Southern Unglaciated Allegheny Plateau	10.32	8.00	5.28	84%	85%
221F	Western Glaciated Allegheny Plateau	2.03	0.96	0.26	81%	85%
221H	Northern Cumberland Plateau	4.61	4.35	3.45	81%	81%
221J	Central Ridge and Valley	1.58	1.43	0.92	81%	86%
222H	Central Till Plains-Beech-Maple	1.76	0.86	0.29	88%	95%
222I	Erie and Ontario Lake Plain	1.63	0.36	0.10	78%	83%
222J	South Central Great Lakes	2.48	1.43	0.75	74%	85%
222K	Southwestern Great Lakes Morainal	1.16	0.70	0.44	78%	83%
222L	North Central U.S. Driftless and Escarpment	2.91	2.06	1.35	81%	85%
222M	Minnesota and Northeast Iowa Morainal-Oak Savannah	1.14	0.37	0.09	73%	91%
222R	Wisconsin Central Sands	0.60	0.47	0.29	55%	60%
222U	Lake Whittlesey Glaciolacustrine Plain	0.62	0.31	0.13	82%	90%
223A	Ozark Highlands	10.62	10.00	8.00	68%	73%
223B	Interior Low Plateau-Transition Hills	1.36	1.18	0.78	89%	91%
223D	Interior Low Plateau-Shawnee Hills	3.10	2.49	1.79	85%	87%
223E	Interior Low Plateau-Highland Rim	5.15	4.43	2.80	80%	84%
223F	Interior Low Plateau-Bluegrass	1.79	1.20	0.35	70%	78%
223G	Central Till Plains-Oak Hickory	1.70	0.81	0.51	85%	88%

		Regeneration eligible forestland			Proportion	
SCT_CD	Section Name	Total	Upland oak	White oak	Upland oak	White oak
		... acres (millions) ...			... % species total ...	
231A	Southern Appalachian Piedmont	7.61	5.98	4.21	63%	67%
231B	Coastal Plains-Middle	7.05	4.57	2.98	54%	58%
231C	Southern Cumberland Plateau	2.14	1.86	1.32	63%	66%
231D	Southern Ridge and Valley	1.91	1.69	1.03	64%	67%
231E	Mid Coastal Plains-Western	5.58	3.67	2.10	56%	61%
231G	Arkansas Valley	1.44	1.17	0.41	49%	58%
231H	Coastal Plains-Loess	5.92	3.66	2.32	68%	72%
231I	Central Appalachian Piedmont	7.46	6.43	5.19	62%	63%
232A	Northern Atlantic Coastal Plain	1.34	0.90	0.64	74%	75%
232B	Gulf Coastal Plains and Flatwoods	9.89	4.21	1.66	53%	57%
232C	Atlantic Coastal Flatwoods	6.16	0.99	0.42	66%	73%
232F	Coastal Plains and Flatwoods-Western Gulf	2.41	1.49	0.76	57%	62%
232H	Middle Atlantic Coastal Plains and Flatwoods	3.44	2.24	1.67	66%	70%
232I	Northern Atlantic Coastal Flatwoods	1.67	0.41	0.24	56%	58%
232J	Southern Atlantic Coastal Plains and Flatwoods	6.52	2.22	0.72	54%	63%
232L	Gulf Coastal Lowlands	2.00	0.15	0.06	49%	69%
234A	Southern Mississippi Alluvial Plain	1.78	0.20	0.10	57%	73%
234D	White and Black River Alluvial Plains	1.92	0.40	0.25	71%	79%
234E	Arkansas Alluvial Plains	0.69	0.31	0.16	64%	72%
251C	Central Dissected Till Plains	4.23	2.39	1.43	78%	83%
251D	Central Till Plains and Grand Prairies	0.60	0.33	0.23	76%	84%
251E	Osage Plains	0.93	0.35	0.06	59%	80%
M211B	New England Piedmont	2.55	1.48	0.19	87%	100%
M221A	Northern Ridge and Valley	8.00	7.20	3.68	81%	84%
M221B	Allegheny Mountains	4.09	2.95	1.32	82%	82%
M221C	Northern Cumberland Mountains	5.23	4.60	2.48	88%	88%
M221D	Blue Ridge Mountains	7.33	6.65	3.19	87%	89%
M223A	Boston Mountains	2.16	2.10	1.72	72%	76%
M231A	Ouachita Mountains	3.13	2.96	2.01	57%	68%
	TOTAL	200.02	131.74	77.64	70.6%	74.6%

TASK 3: SUMMARIZE CANOPY, SAPLING, AND SEEDLING POPULATIONS OF REGENERATION ELIGIBLE AREAS

Across regeneration eligible upland oak forestland, there are about 550 trees per acre (dbh ≥ 1 in.) of all species, on average, of which white oak averages about 4% and upland oaks together average about 12% (Table 3). On regeneration eligible upland oak forestland, most trees tend to be in either overtopped or codominant canopy positions. Intermediate trees are common though noticeably less abundant than canopy positions below or immediately above. Across the range, trees of all species in a dominant canopy position were rare, averaging ≈ 3 trees per acre.

Across all regeneration eligible upland oak forestland in the region under consideration, the total Gingrich stocking value for all species (dbh ≥ 1 in.) averages about 109, but ranges from ≈ 96 – 147 (Figure 11).

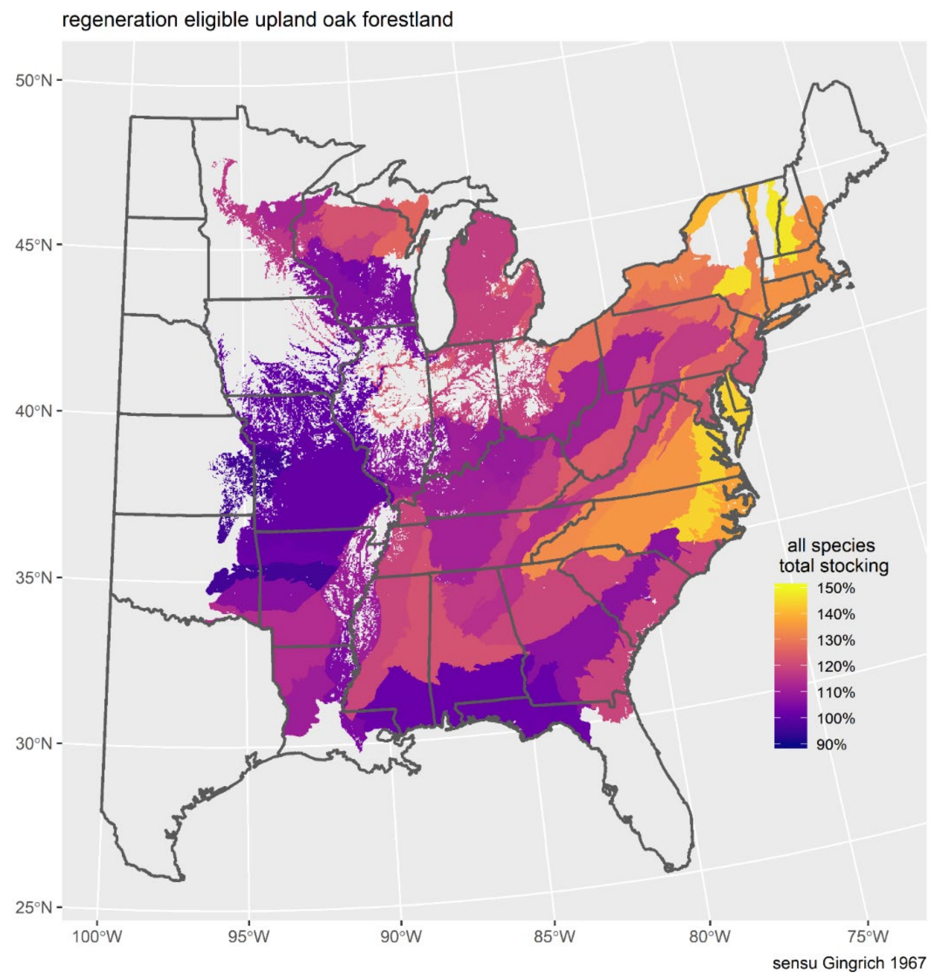


Figure 11. All species total Gingrich stocking by ecological section, (dbh ≥ 1 in.), eastern US regeneration eligible upland oak forestland, 2017.

Table 3. Abundance and relative abundance by canopy position and ecological section, trees per acre (dbh ≥ 1 in.), eastern US regeneration eligible upland oak forestland, 2017. OVT = overtopped, INT = intermediate, CoD = codominant, DOM = dominant.

		All species				Upland oaks				White oak			
SCT_CD	Section Name	OVT	INT	CoD	DOM	OVT	INT	CoD	DOM	OVT	INT	CoD	DOM
		... trees per acre ...				...% All species...							
211E	St. Lawrence and Champlain Valley	482	135	122	2	9%	5%	16%	12%	1%	0%	2%	0%
211F	Northern Glaciated Allegheny Plateau	312	63	108	1	5%	10%	29%	39%	1%	3%	6%	3%
211G	Northern Unglaciated Allegheny Plateau	277	73	100	3	6%	15%	34%	41%	2%	6%	8%	13%
211I	Catskill Mountains	385	56	127	1	3%	4%	22%	18%	0%	1%	1%	0%
212H	Northern Lower Peninsula	321	110	121	4	10%	18%	22%	18%	4%	7%	6%	4%
212K	Western Superior Uplands	288	195	145	4	6%	6%	12%	20%	1%	1%	1%	2%
212Q	North Central Wisconsin Uplands	368	96	97	5	6%	9%	22%	30%	1%	3%	5%	11%
212T	Northern Green Bay Lobe	349	138	126	5	6%	7%	9%	17%	0%	0%	1%	0%
212X	Northern Highlands	430	153	116	4	4%	6%	15%	19%	0%	0%	1%	2%
221A	Lower New England	351	56	104	2	8%	17%	30%	18%	2%	4%	5%	2%
221B	Hudson Valley	305	52	89	3	5%	9%	27%	18%	2%	1%	4%	2%
221D	Northern Appalachian Piedmont	250	60	67	3	8%	14%	35%	45%	4%	5%	9%	15%
221E	Southern Unglaciated Allegheny Plateau	313	68	80	4	7%	13%	28%	24%	2%	4%	9%	8%
221F	Western Glaciated Allegheny Plateau	299	67	82	4	4%	5%	12%	32%	0%	0%	2%	9%
221H	Northern Cumberland Plateau	439	85	92	4	6%	14%	31%	21%	2%	5%	12%	10%
221J	Central Ridge and Valley	383	71	86	7	8%	16%	27%	22%	3%	4%	6%	8%
222H	Central Till Plains-Beech-Maple	350	58	64	6	3%	8%	16%	29%	0%	1%	5%	9%
222I	Erie and Ontario Lake Plain	370	53	105	1	6%	10%	20%	27%	0%	0%	2%	0%
222J	South Central Great Lakes	292	79	78	6	8%	22%	30%	26%	2%	8%	7%	6%
222K	Southwestern Great Lakes Morainal	205	76	80	4	9%	11%	28%	41%	5%	4%	12%	12%
222L	North Central U.S. Driftless and Escarpment	299	104	69	4	5%	12%	32%	24%	2%	4%	10%	5%
222M	Minnesota & NE Iowa Morainal-Oak Savannah	314	101	107	4	3%	2%	16%	41%	1%	0%	3%	9%
222R	Wisconsin Central Sands	278	126	141	12	11%	20%	15%	28%	5%	6%	6%	8%
222U	Lake Whittlesey Glaciolacustrine Plain	331	115	71	12	3%	5%	15%	18%	1%	2%	5%	8%
223A	Ozark Highlands	313	107	93	4	16%	29%	57%	56%	8%	12%	19%	16%
223B	Interior Low Plateau-Transition Hills	296	71	72	2	4%	15%	30%	27%	2%	4%	9%	11%
223D	Interior Low Plateau-Shawnee Hills	320	84	94	3	7%	14%	21%	22%	3%	4%	8%	10%
223E	Interior Low Plateau-Highland Rim	360	73	80	5	6%	12%	26%	21%	2%	4%	10%	8%
223F	Interior Low Plateau-Bluegrass	296	88	85	3	9%	11%	18%	28%	1%	2%	4%	8%
223G	Central Till Plains-Oak Hickory	288	59	73	3	4%	10%	28%	23%	2%	4%	12%	7%
231A	Southern Appalachian Piedmont	399	96	131	2	8%	12%	15%	6%	4%	4%	6%	2%
231B	Coastal Plains-Middle	463	92	134	4	8%	11%	12%	12%	4%	5%	5%	9%
231C	Southern Cumberland Plateau	419	66	123	3	9%	16%	26%	4%	4%	5%	8%	4%
231D	Southern Ridge and Valley	418	88	125	1	10%	15%	23%	54%	3%	4%	4%	11%

		All species				Upland oaks				White oak			
SCT_CD	Section Name	OVT	INT	CoD	DOM	OVT	INT	CoD	DOM	OVT	INT	CoD	DOM
		… trees per acre …				…% All species…							
231E	Mid Coastal Plains-Western	439	88	136	2	8%	7%	10%	23%	4%	2%	4%	2%
231G	Arkansas Valley	300	78	125	2	13%	19%	32%	26%	3%	1%	3%	0%
231H	Coastal Plains-Loess	476	68	94	4	8%	12%	16%	14%	4%	5%	6%	10%
231I	Central Appalachian Piedmont	473	78	164	4	9%	15%	17%	16%	4%	7%	7%	10%
232A	Northern Atlantic Coastal Plain	244	110	80	2	11%	21%	37%	26%	5%	10%	16%	7%
232B	Gulf Coastal Plains and Flatwoods	359	86	116	4	6%	8%	7%	7%	2%	2%	3%	6%
232C	Atlantic Coastal Flatwoods	383	115	160	7	6%	4%	4%	1%	3%	2%	2%	1%
232F	Coastal Plains and Flatwoods-Western Gulf	351	60	129	2	9%	11%	9%	6%	3%	2%	3%	3%
232H	Middle Atlantic Coastal Plains & Flatwoods	479	119	128	4	5%	8%	14%	22%	2%	3%	7%	9%
232I	Northern Atlantic Coastal Flatwoods	395	188	157	2	4%	3%	5%	6%	2%	1%	4%	0%
232J	Southern Atlantic Coastal Plains & Flatwoods	319	88	158	2	8%	9%	9%	24%	2%	2%	2%	2%
232L	Gulf Coastal Lowlands	369	80	113	1	2%	4%	2%	0%	1%	1%	1%	0%
234A	Southern Mississippi Alluvial Plain	325	57	87	4	9%	2%	7%	0%	2%	1%	1%	0%
234D	White and Black River Alluvial Plains	390	60	114	3	9%	9%	15%	25%	4%	5%	5%	14%
234E	Arkansas Alluvial Plains	353	43	120	8	5%	10%	18%	0%	2%	5%	3%	0%
251C	Central Dissected Till Plains	257	73	76	5	5%	12%	35%	35%	2%	4%	17%	13%
251D	Central Till Plains and Grand Prairies	288	85	86	5	7%	5%	24%	30%	2%	2%	11%	4%
251E	Osage Plains	252	77	73	3	5%	17%	28%	31%	0%	3%	3%	0%
M211B	New England Piedmont	447	92	119	3	4%	7%	17%	20%	0%	0%	0%	0%
M221A	Northern Ridge and Valley	287	75	103	2	10%	18%	45%	47%	2%	3%	8%	6%
M221B	Allegheny Mountains	308	86	95	1	6%	11%	34%	20%	1%	2%	6%	3%
M221C	Northern Cumberland Mountains	433	70	93	2	5%	13%	29%	27%	1%	3%	6%	5%
M221D	Blue Ridge Mountains	346	55	96	2	7%	18%	37%	13%	1%	3%	5%	2%
M223A	Boston Mountains	339	78	114	3	9%	15%	40%	53%	4%	5%	16%	24%
M231A	Ouachita Mountains	482	135	122	2	9%	5%	16%	12%	1%	0%	2%	0%
	Area-weighted average	359	83	107	3	8%	14%	25%	25%	3%	5%	7%	8%

The aforementioned pattern of increasing oak relative abundance with canopy position is perhaps more apparent in terms of growing space occupancy i.e., Gingrich stocking (Table 4). Across the range, white oaks (dbh ≥ 1 in.) average a Gingrich stocking value of about 9, with ≈ 2 in overtopped and intermediate canopy positions but ≈ 7 in codominant and dominant canopy positions in regeneration eligible forestland. This equates to about 8% of the total stocking across all species and sizes, 5% of total lower canopy stocking and 10% of total upper canopy.

Five large ecological sections (regeneration eligible upland oak acres ≥ 1 million) have white oak upper canopy Gingrich stocking ≳ 10 (Figure 12), including the Central Dissected Till Plains (251c; 13.4), Ozark Highlands (223A; 13.3), Boston Mountains (M223A; 13.0), Central Appalachian Piedmont (231I; 9.64, and Northern Cumberland Plateau (221H; 9.5). However, canopy populations can also vary within an ecological section, suggesting more localized drivers and management influence canopy composition. For example, white oak stocking can be considerably higher locally within an ecological section (Figure 13). Local scale visualizations also bolster the perception that the Interior Highlands of Missouri and Arkansas are an iconic location for white oak dominated forests.

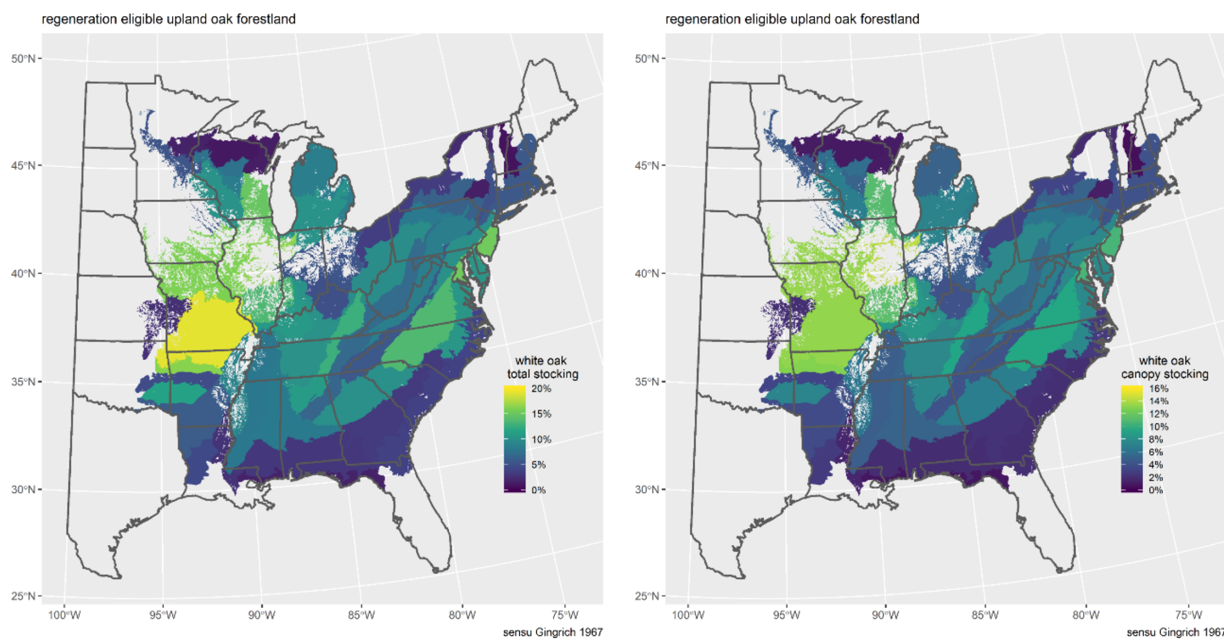


Figure 12. White oak total and upper canopy Gingrich stocking by ecological section, total (dbh ≥ 1 in.) [L], upper canopy (dominant or codominant) [R], eastern US regeneration eligible upland oak forestland, 2017.

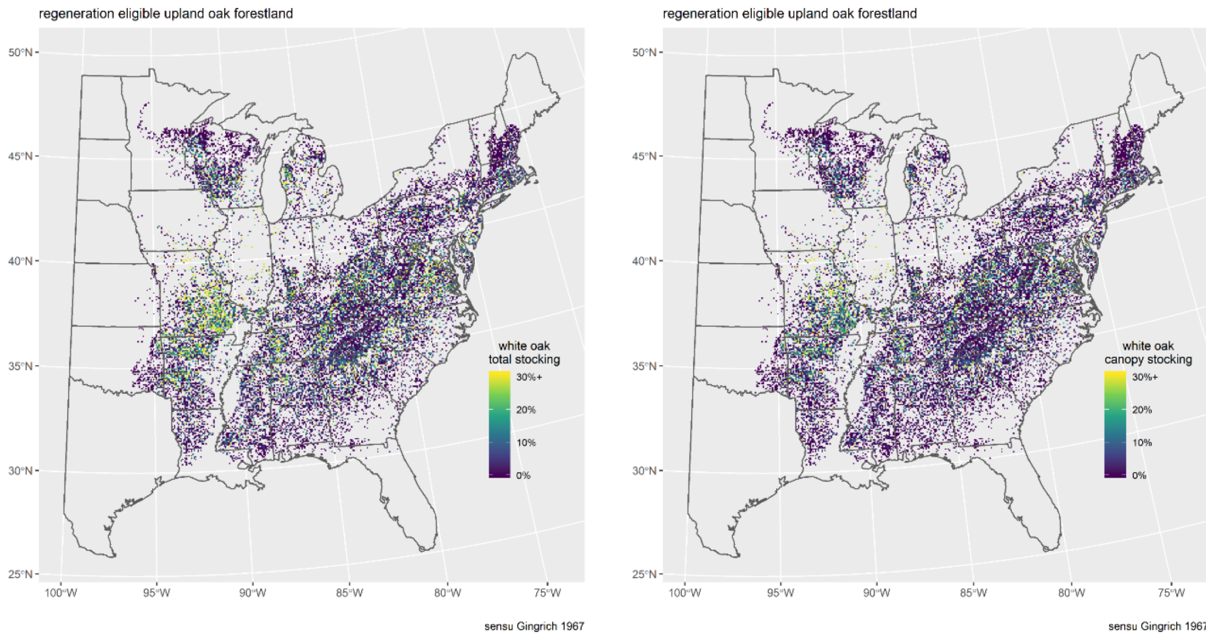


Figure 13. White oak total and upper canopy Gingrich stocking, local scale, total (dbh ≥ 1 in.) [L], upper canopy (dominant or codominant) [R], eastern US regeneration eligible upland oak forestland, 2017. Each cell represents ≈12,000 acres.

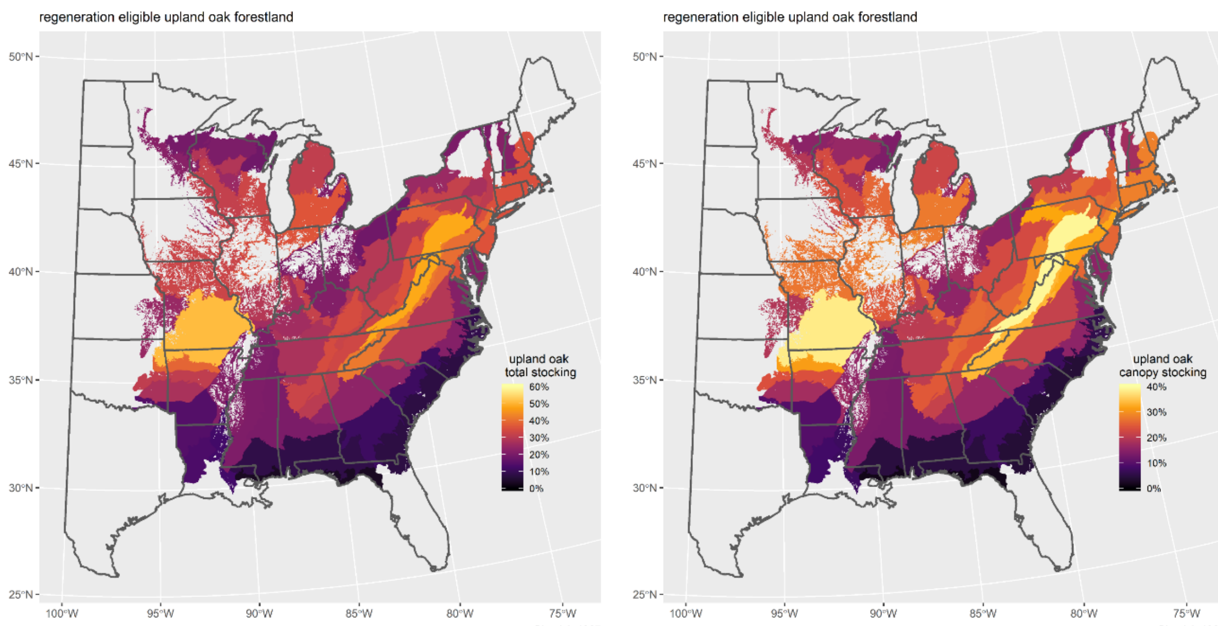


Figure 14. Upland oak total and upper canopy Gingrich stocking by ecological section, total (dbh ≥ 1 in.) [L], upper canopy (dominant or codominant) [R], eastern US regeneration eligible upland oak forestland, 2017.

Upland oaks together average a Gingrich stocking value of ≈ 29, which comprises about 27% of all species, with 14% of the total lower canopy and 35% of the total upper canopy. Upland oak upper canopy Gingrich stocking is ≳ 30 for 7 large ecological sections (Figure 14), including the Ozark Highlands (223A), M221A, M221D, Northern Appalachian Piedmont (221D), Northern Unglaciated Allegheny Plateau (211G), Boston Mountains (M223A) and all Central Appalachian

Mountain sections (M221) except the Northern Cumberland Mountains (M221C; 26). Upland oak upper canopy Gingrich stocking approached 40 in both the Northern Ridge and Valley and Ozark Highlands sections (M221A, 223A). Upland oak stocking can be considerably higher locally within an ecological section (Figure 15). Local scale visualizations also reinforce the broader Appalachian region and Interior Highlands of Missouri and Arkansas as hotspots for upland oak dominated forests, and highlight the Appalachian region as having a diverse suite of upper canopy upland oak species that are not white oak.

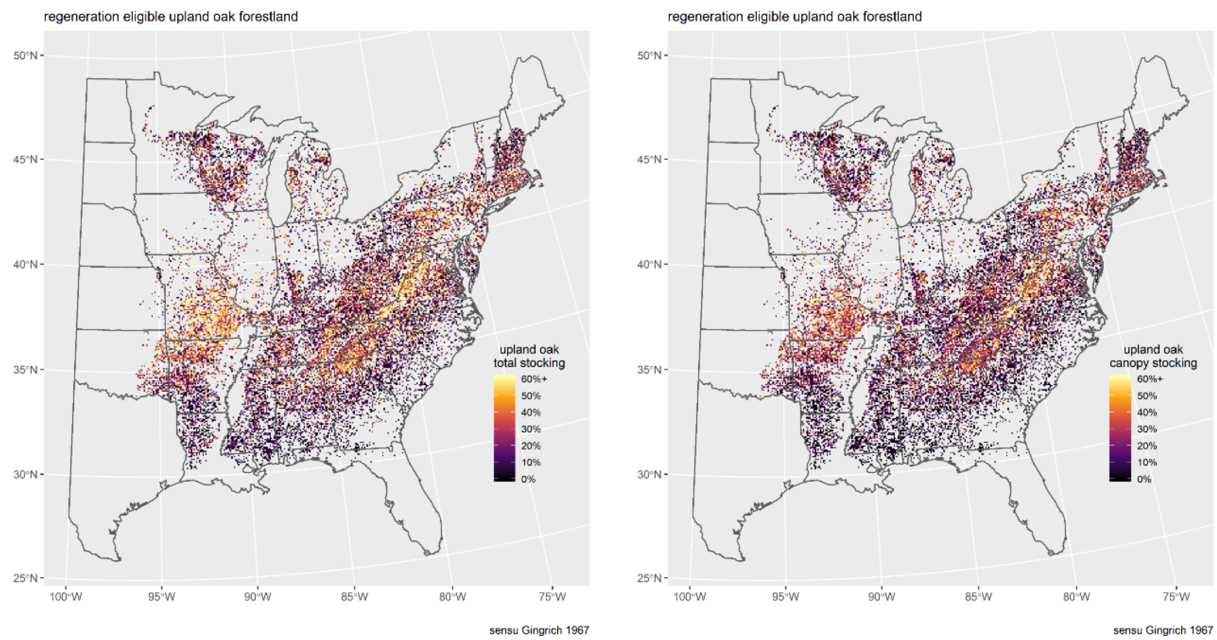


Figure 15. Upland oak total and upper canopy Gingrich stocking, local scale, total (dbh ≥ 1 in.) [L], upper canopy (dominant or codominant) [R], eastern US regeneration eligible upland oak forestland, 2017. Each cell represents ≈12,000 acres.

Table 4. Gingrich stocking by canopy position, species, and ecological section, (dbh ≥ 1 in.), eastern US regeneration eligible upland oak forestland, 2017. OVT = overtopped, INT = intermediate, CoD = codominant, DOM = dominant.

		All species				Upland oaks				White oak			
SCT_CD	Section Name	OVT	INT	CoD	DOM	OVT	INT	CoD	DOM	OVT	INT	CoD	DOM
		... Gingrich Stocking...					...% All species...						
211E	St. Lawrence and Champlain Valley	36	21	72	3	7%	7%	21%	10%	1%	1%	3%	0%
211F	Northern Glaciated Allegheny Plateau	31	15	74	2	7%	16%	36%	47%	2%	4%	7%	4%
211G	Northern Unglaciated Allegheny Plateau	29	16	69	4	8%	17%	45%	46%	3%	5%	9%	11%
211I	Catskill Mountains	40	13	84	2	6%	7%	29%	18%	1%	2%	2%	0%
212H	Northern Lower Peninsula	24	19	65	3	15%	23%	33%	31%	6%	10%	8%	9%
212K	Western Superior Uplands	17	21	65	3	7%	10%	23%	29%	2%	3%	2%	2%
212Q	North Central Wisconsin Uplands	25	17	61	7	9%	15%	33%	46%	3%	5%	8%	16%
212T	Northern Green Bay Lobe	26	21	64	7	6%	8%	19%	29%	1%	1%	2%	0%
212X	Northern Highlands	27	21	61	4	5%	10%	26%	26%	1%	1%	2%	3%
221A	Lower New England	34	14	77	3	9%	22%	37%	20%	3%	6%	6%	2%
221B	Hudson Valley	32	14	75	4	6%	12%	34%	26%	2%	2%	6%	3%
221D	Northern Appalachian Piedmont	24	17	70	5	12%	21%	44%	43%	5%	6%	10%	13%
221E	Southern Unglaciated Allegheny Plateau	27	15	58	5	11%	18%	38%	39%	4%	7%	13%	12%
221F	Western Glaciated Allegheny Plateau	31	17	66	7	5%	6%	18%	52%	1%	1%	3%	18%
221H	Northern Cumberland Plateau	34	15	58	2	11%	23%	45%	43%	5%	9%	16%	17%
221J	Central Ridge and Valley	33	16	55	4	12%	28%	42%	44%	4%	6%	8%	7%
222H	Central Till Plains-Beech-Maple	31	15	55	10	5%	10%	25%	41%	2%	2%	7%	11%
222I	Erie and Ontario Lake Plain	33	14	74	3	8%	10%	26%	48%	1%	1%	5%	0%
222J	South Central Great Lakes	26	18	62	7	12%	25%	42%	37%	5%	10%	11%	8%
222K	Southwestern Great Lakes Morainal	18	16	61	5	13%	23%	40%	46%	6%	12%	18%	18%
222L	North Central U.S. Driftless and Escarpment	22	23	50	4	10%	25%	45%	33%	5%	10%	14%	6%
222M	Minnesota & NE Iowa Morainal-Oak Savannah	23	16	65	5	6%	8%	27%	51%	2%	2%	7%	13%
222R	Wisconsin Central Sands	17	15	54	12	13%	27%	24%	40%	7%	13%	8%	11%
222U	Lake Whittlesey Glaciolacustrine Plain	26	22	54	13	4%	11%	24%	34%	2%	6%	8%	20%
223A	Ozark Highlands	20	16	54	5	23%	40%	67%	66%	12%	17%	24%	19%
223B	Interior Low Plateau-Transition Hills	25	16	59	3	9%	23%	42%	34%	4%	7%	13%	17%
223D	Interior Low Plateau-Shawnee Hills	24	16	61	4	9%	17%	32%	31%	4%	6%	14%	16%
223E	Interior Low Plateau-Highland Rim	32	16	53	4	11%	19%	37%	32%	5%	7%	14%	11%
223F	Interior Low Plateau-Bluegrass	27	18	56	3	9%	12%	26%	45%	1%	3%	7%	14%
223G	Central Till Plains-Oak Hickory	22	14	57	5	7%	14%	42%	24%	5%	6%	20%	7%
231A	Southern Appalachian Piedmont	28	14	69	1	13%	17%	24%	18%	6%	7%	10%	8%
231B	Coastal Plains-Middle	34	14	66	2	12%	16%	20%	21%	5%	7%	8%	10%
231C	Southern Cumberland Plateau	31	11	67	1	15%	24%	37%	17%	7%	8%	12%	14%
231D	Southern Ridge and Valley	30	12	65	1	17%	24%	33%	39%	5%	6%	7%	7%

		All species				Upland oaks				White oak			
SCT_CD	Section Name	OVT	INT	CoD	DOM	OVT	INT	CoD	DOM	OVT	INT	CoD	DOM
		... Gingrich Stocking...				...% All species...							
231E	Mid Coastal Plains-Western	28	9	67	1	10%	12%	14%	26%	5%	5%	6%	7%
231G	Arkansas Valley	21	10	58	2	17%	26%	41%	35%	5%	3%	6%	0%
231H	Coastal Plains-Loess	36	13	60	3	11%	16%	22%	22%	6%	6%	8%	9%
231I	Central Appalachian Piedmont	34	13	77	3	12%	20%	27%	29%	7%	9%	12%	18%
232A	Northern Atlantic Coastal Plain	23	23	67	3	14%	25%	38%	38%	8%	12%	16%	12%
232B	Gulf Coastal Plains and Flatwoods	26	12	56	3	8%	10%	9%	8%	3%	3%	4%	6%
232C	Atlantic Coastal Flatwoods	25	15	71	2	9%	8%	6%	5%	5%	4%	3%	5%
232F	Coastal Plains and Flatwoods-Western Gulf	25	9	68	1	13%	19%	12%	7%	5%	5%	4%	5%
232H	Middle Atlantic Coastal Plains & Flatwoods	36	19	77	4	8%	14%	20%	26%	4%	7%	10%	14%
232I	Northern Atlantic Coastal Flatwoods	27	24	78	2	5%	6%	8%	29%	3%	3%	4%	0%
232J	Southern Atlantic Coastal Plains & Flatwoods	22	11	67	2	10%	11%	11%	39%	3%	3%	4%	11%
232L	Gulf Coastal Lowlands	23	12	58	2	4%	10%	3%	0%	3%	2%	2%	0%
234A	Southern Mississippi Alluvial Plain	24	10	61	2	15%	5%	12%	0%	4%	2%	3%	0%
234D	White and Black River Alluvial Plains	30	10	60	3	9%	15%	25%	39%	5%	8%	10%	21%
234E	Arkansas Alluvial Plains	23	7	71	2	12%	24%	25%	0%	5%	10%	6%	0%
251C	Central Dissected Till Plains	20	15	53	7	10%	20%	47%	46%	5%	10%	24%	18%
251D	Central Till Plains and Grand Prairies	24	18	66	7	8%	20%	40%	51%	4%	5%	22%	5%
251E	Osage Plains	19	16	50	5	8%	22%	36%	35%	1%	4%	5%	0%
M211B	New England Piedmont	41	17	77	4	5%	10%	23%	19%	1%	1%	1%	0%
M221A	Northern Ridge and Valley	26	16	68	2	16%	27%	57%	58%	4%	5%	10%	7%
M221B	Allegheny Mountains	29	18	69	2	10%	19%	43%	28%	3%	4%	8%	5%
M221C	Northern Cumberland Mountains	34	14	65	2	9%	20%	39%	45%	3%	6%	9%	7%
M221D	Blue Ridge Mountains	34	14	76	2	11%	24%	45%	22%	2%	4%	6%	4%
M223A	Boston Mountains	24	10	60	3	16%	26%	51%	60%	9%	11%	22%	23%
M231A	Ouachita Mountains	21	13	64	1	22%	32%	28%	25%	11%	13%	12%	11%
	Area-weighted average	28	15	65	3	11%	20%	35%	37%	4%	7%	10%	11%

Saplings of all species (dbh 1-3 in.) average 310 trees per acre (Table 5) but white oaks average only 8 trees per acre (< 3%), and upland oaks 23 (> 7%). White oak saplings average ≤ 1 trees per acre in eleven ecological sections and < 20 in all sections (Figure 16). The highest white oak sapling relative abundance is in the Wisconsin Central Sands (222R, 9%), Ozark Highlands, and Ouachita Mountains (223A, M23A; 7%). Upland oak saplings are generally more abundant than white oak alone, but still relatively scarce (Figure 17), and appears to be driven by white oak.

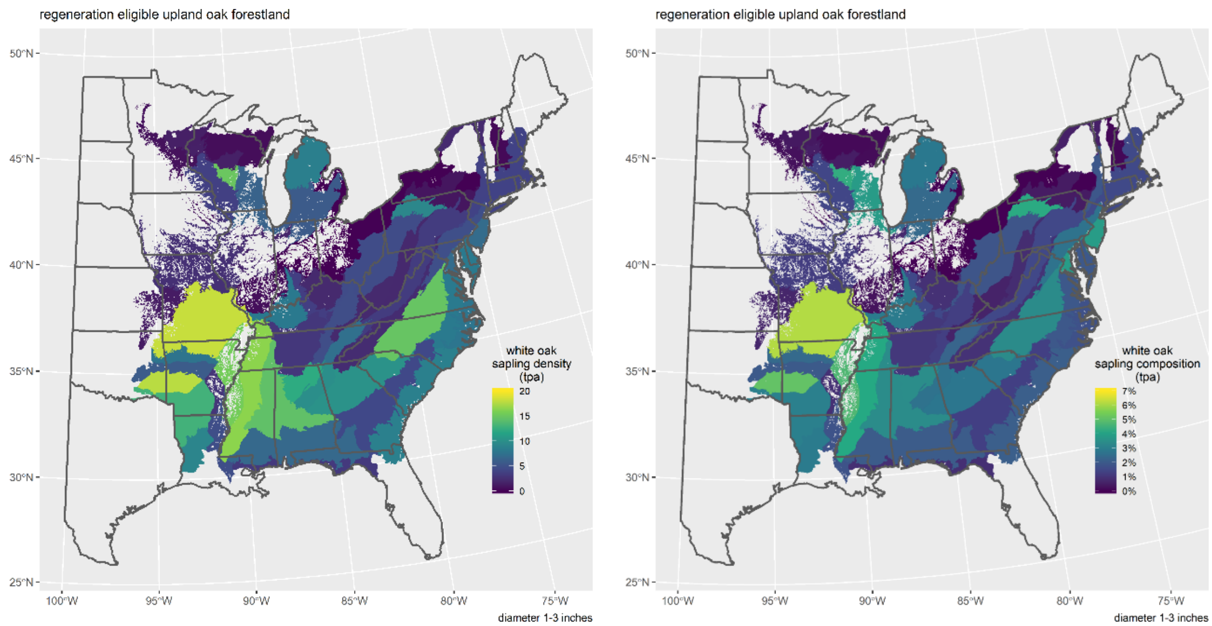


Figure 16. White oak sapling abundance and relative abundance by ecological section, trees per acre (1-3 in. dbh) [L], % trees per acre (1-3 in. dbh) [R], eastern US regeneration eligible upland oak forestland, 2017.

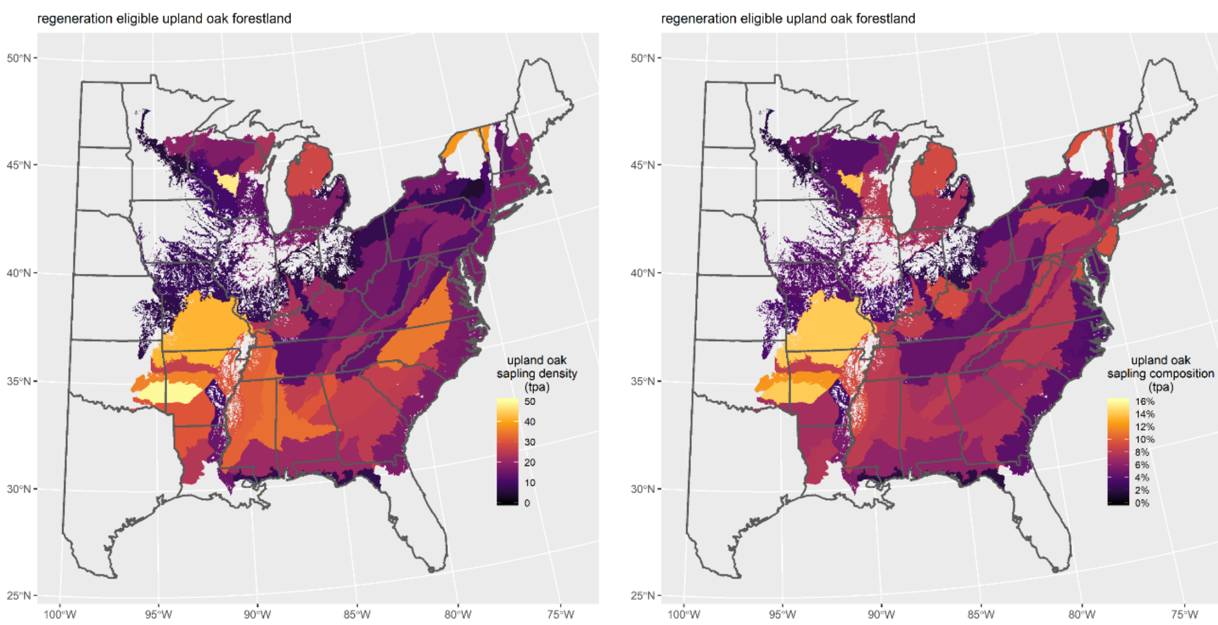


Figure 17. Upland oak sapling abundance and relative abundance by ecological section, trees per acre (1-3 in. dbh) [L], % trees per acre (1-3 in. dbh) [R], eastern US regeneration eligible upland oak forestland, 2017

Seedling abundance is variable, ranging from about 900-4000 per acre for all species across all ecological sections with an average of 2110 (Table 5). White oaks average 98 seedlings per acre (<5%), but range ≈ 3-279 trees per acre across sections (Figure 18). White oaks make up < 2% of seedlings in 25 ecological sections (Figure 19) and >10% in 5 sections with the largest shares in the Central Till Plains and Grand Prairies (251D; 29%) and Ozark Highlands (223A; 18%).

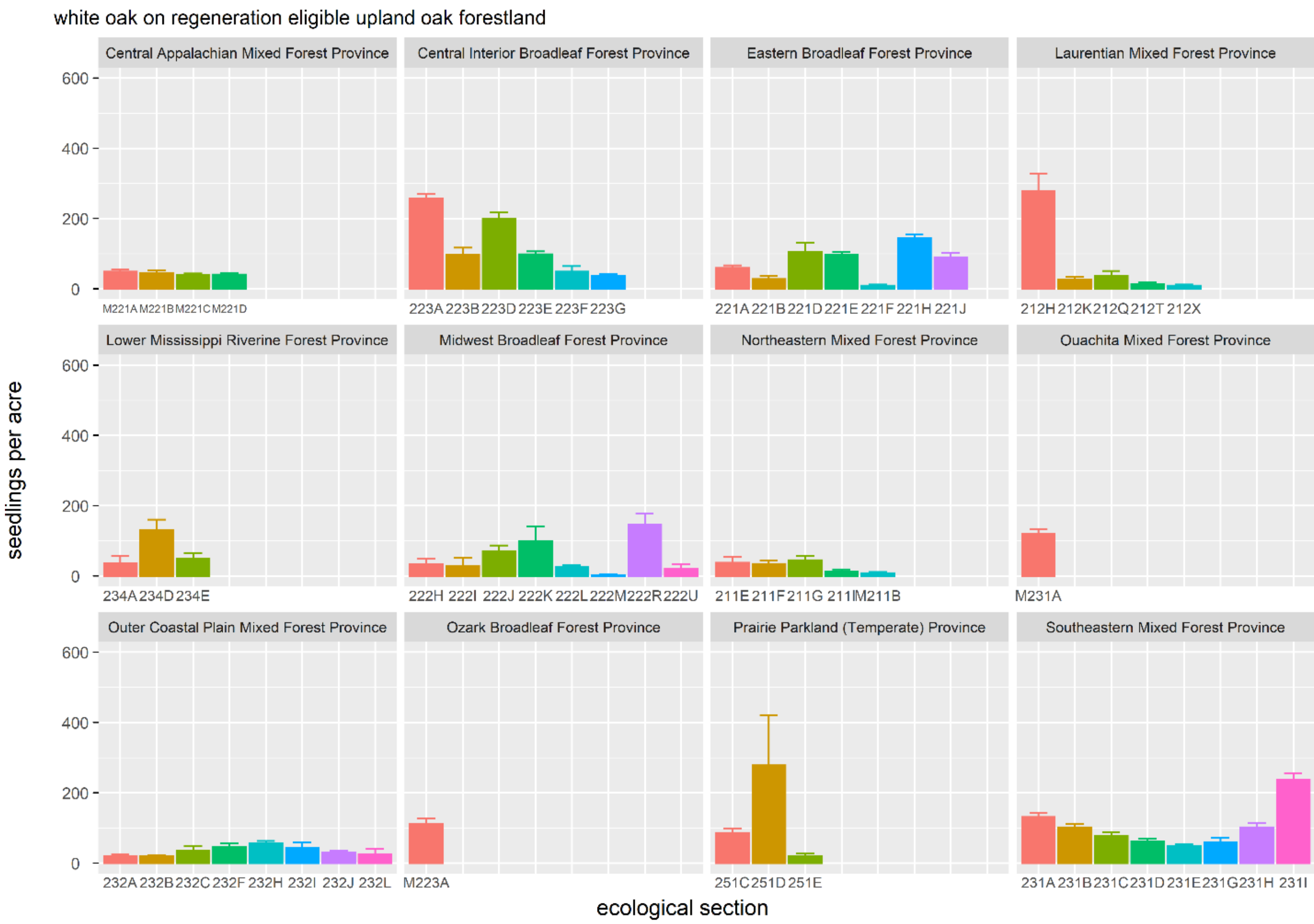


Figure 18. White oak seedling abundance by ecological section, trees per acre (dbh < 1 in; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Errorbars depict sampling error (≈ 68% confidence or 1 standard deviation). Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

Figure 19. White oak seedling relative abundance by ecological section, % trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

Upland oak seedlings range from about 44-591 across sections and average 271 seedlings per acre (13%) (Table 5). Only 8 ecological sections averaged >400 upland oak seedlings per acre (Figure 20) including the Shawnee Hills [223D], Boston Mountains [M223A], Central Appalachian Piedmont [231I], Northern Cumberland Plateau [221H], Arkansas Valley [231G], Ozark Highlands [223A], Wisconsin Central Sands [222R], Northern Lower Peninsula [212H]. Upland oaks make up ≥ 20% of the seedling population in 6 ecological sections (Wisconsin Central Sands [222R], Northern Lower Peninsula [212H], Arkansas Valley [231G], Ozark Highlands [223A], Ouachita Mountains [M231A], Arkansas Alluvial Plains [234E]), but < 5% in 9 sections (Figure 21).

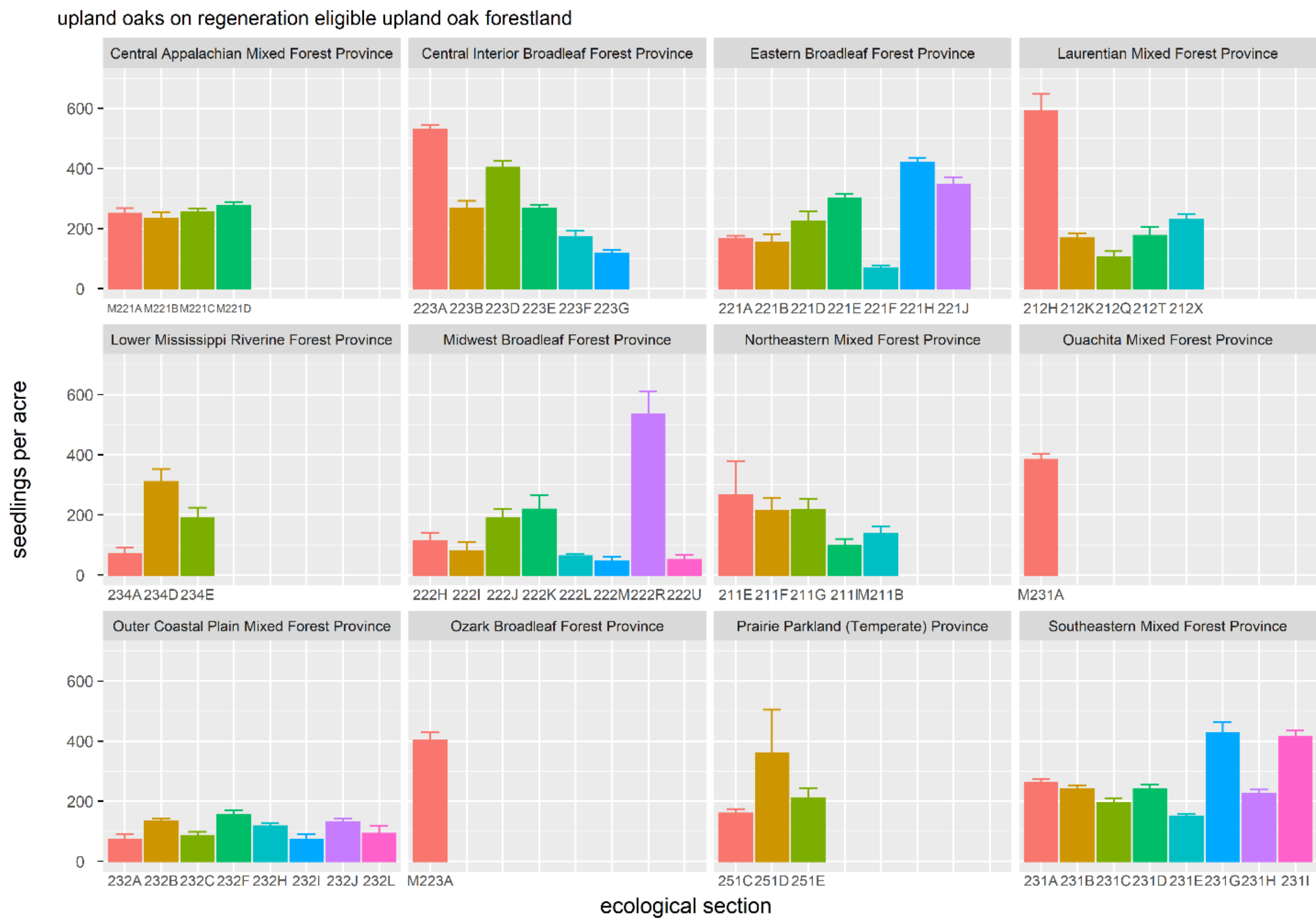


Figure 20. Upland oak seedling abundance by ecological section, trees per acre (dbh < 1 in; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Errorbars depict sampling error (≈ 68% confidence or 1 standard deviation). Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

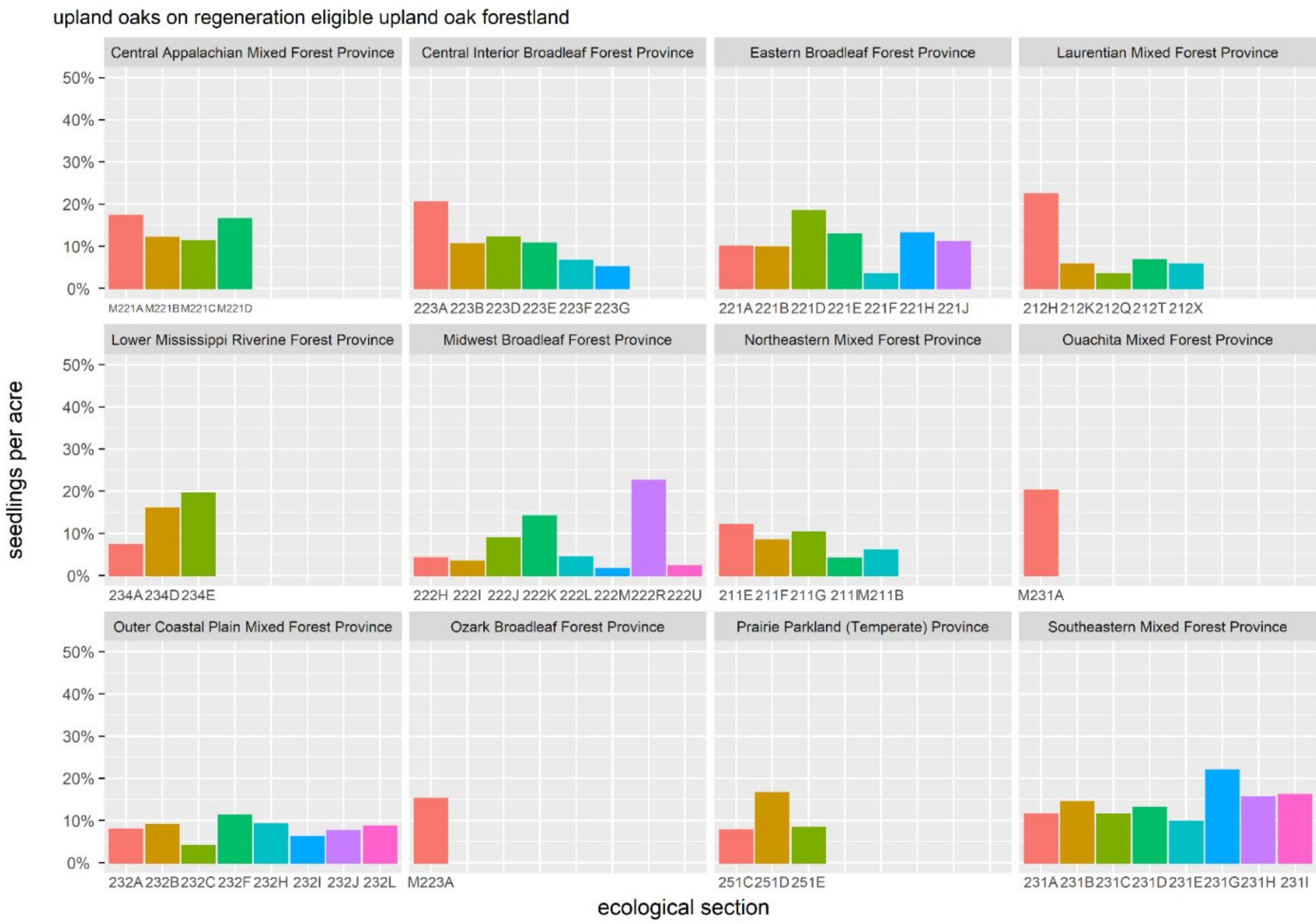


Figure 21. Upland oak seedling relative abundance by ecological section, % trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

Even within an ecological section, seedling and sapling presence and abundance is often spatially variable, suggesting that more localized, stand-level drivers and adaptive silviculture will be important determinants of stand development and regeneration outcomes for white (Figure 22) and upland oaks (Figure 23).

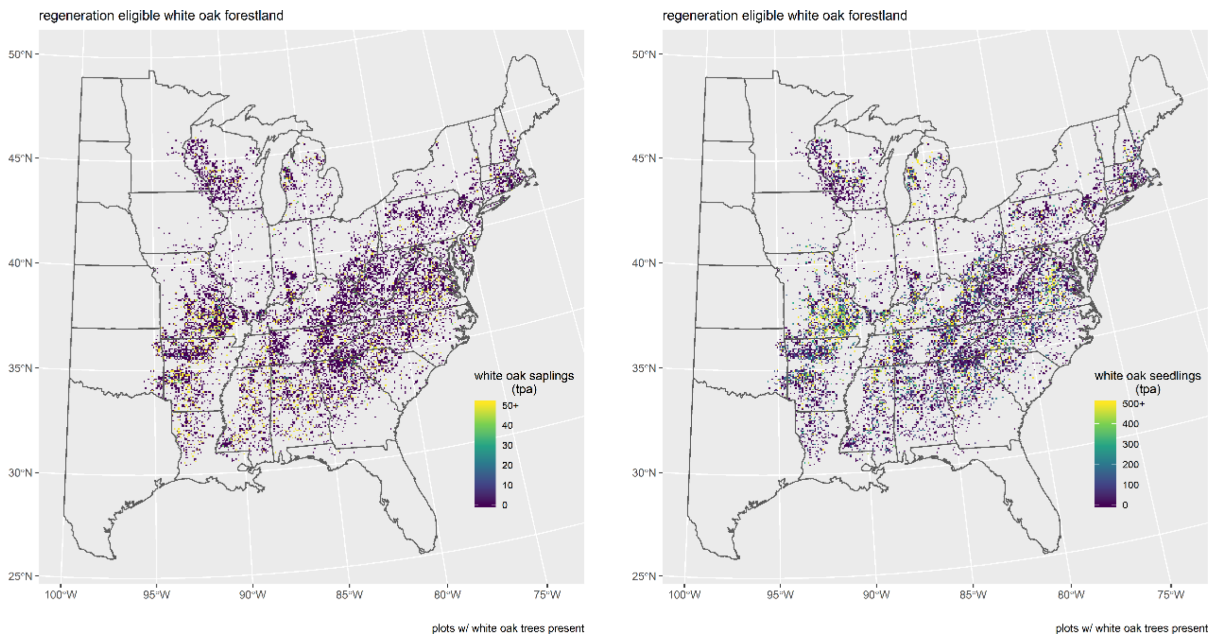


Figure 22. White oak sapling and seedling abundance, local scale, trees per acre, saplings (dbh 1-3 in.) [L], seedlings (dbh < 1 in; height ≥ 12 in.) [R], eastern US regeneration eligible white oak forestland, 2017. Each cell represents ≈ 12,000 acres.

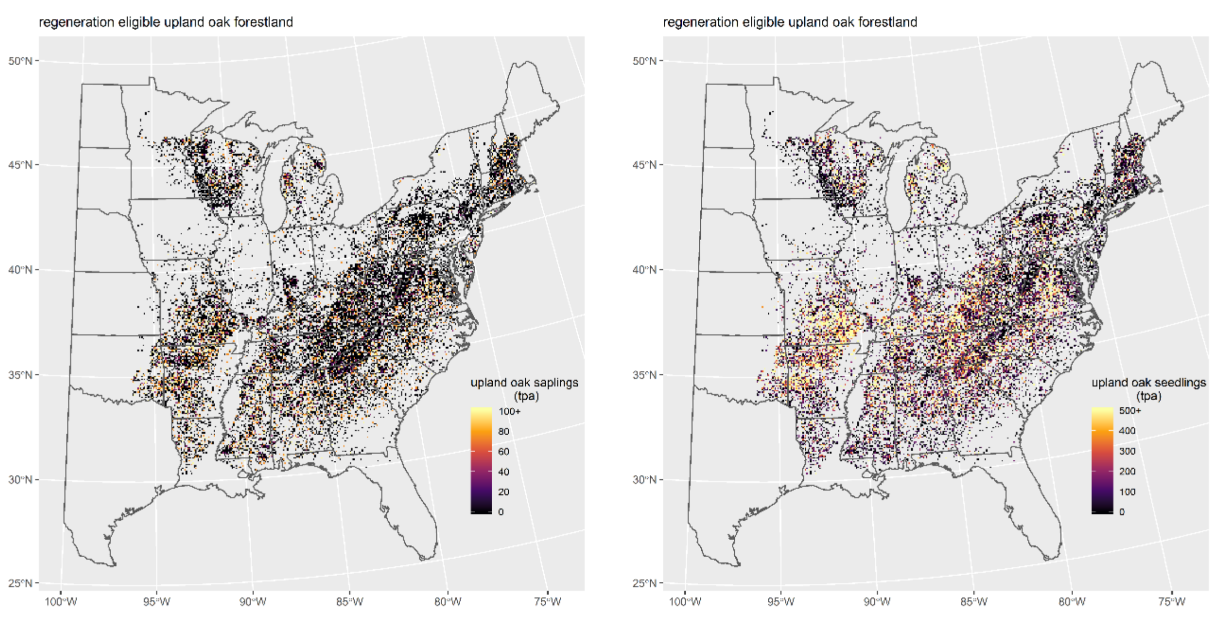


Figure 23. Upland oak sapling and seedling abundance, local scale, trees per acre, saplings (dbh 1-3 in.) [L], seedlings (dbh < 1 in; height ≥ 12 in.) [R], eastern US regeneration eligible white oak forestland, 2017. Each cell represents ≈ 12,000 acres.

Upland oaks and many other hardwood species can regenerate from vegetative reproduction, also known as sprouting. Sprouting is an important reproduction source for upland oaks and sprouts are often highly competitive during the regeneration process. While oak sprouts can alleviate some deficit in seedlings and sapling populations in a regeneration event, not all stems will sprout. Oak sprouting probabilities tend to decrease with increasing stem diameter (**Figure 24**). Across the range, an average of 7 potential white oak sprouts (dbh ≥ 3 in.) per acre may be available to bolster seedling and sapling populations (**Table 5**). Upland oaks average 32 potential sprouts per acre. The abundance of potential sprouts for both white and upland oaks varied considerably across ecological sections (**Figure 25**), but white oak potential sprouts were generally highest in the broader Interior Highlands region of Missouri and Arkansas (and North Atlantic Coastal Plain [232A], whereas other upland oaks potential sprouts were relatively more abundant and the broader Appalachian region. The variable, but relatively higher abundance of potential sprouts in these regions is further highlighted at local scale (**Figure 26**).

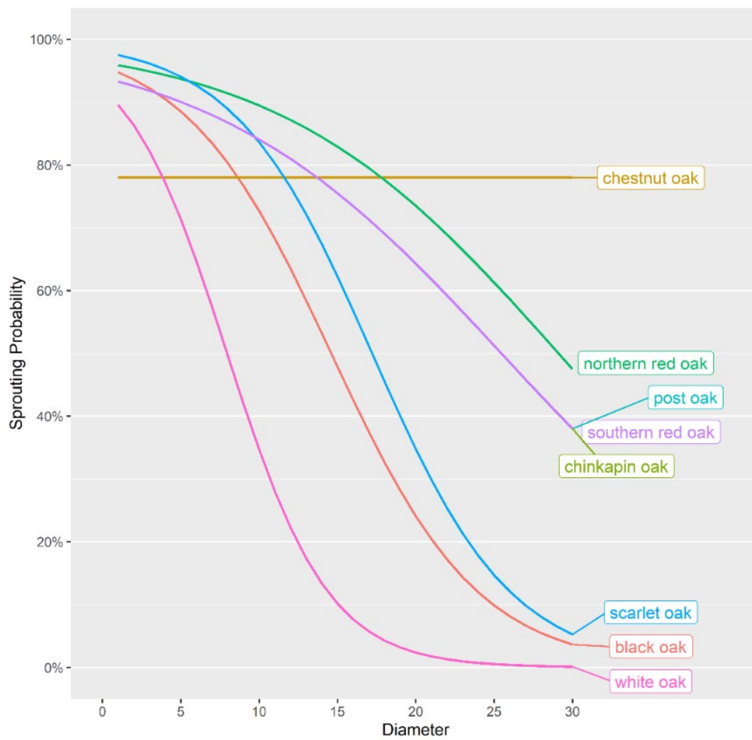


Figure 24. Upland oak sprouting probability estimates by species and diameter[1].

[1] Estimates based on models used by USFS Forest Vegetation Simulator, Southern Variant (Keyser 2008)

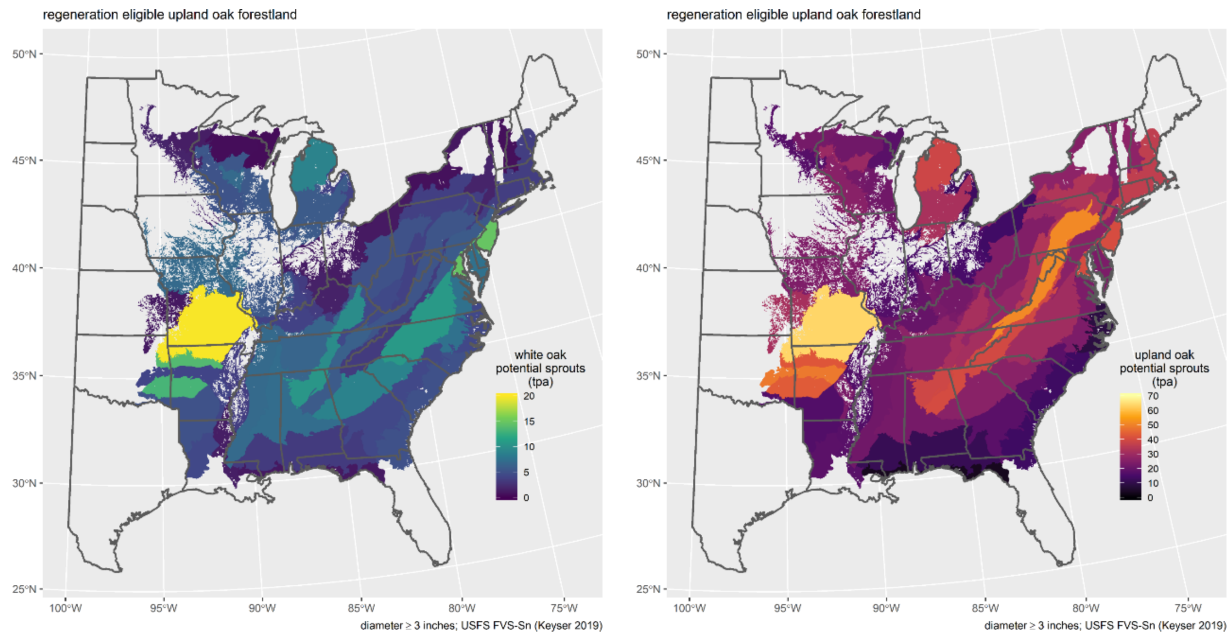


Figure 25. White and upland oak potential sprout abundance by ecological section, potential trees per acre (dbh ≥ 3 in.), white oak [L], upland oak [R][1], eastern US regeneration eligible upland oak forestland, 2017.

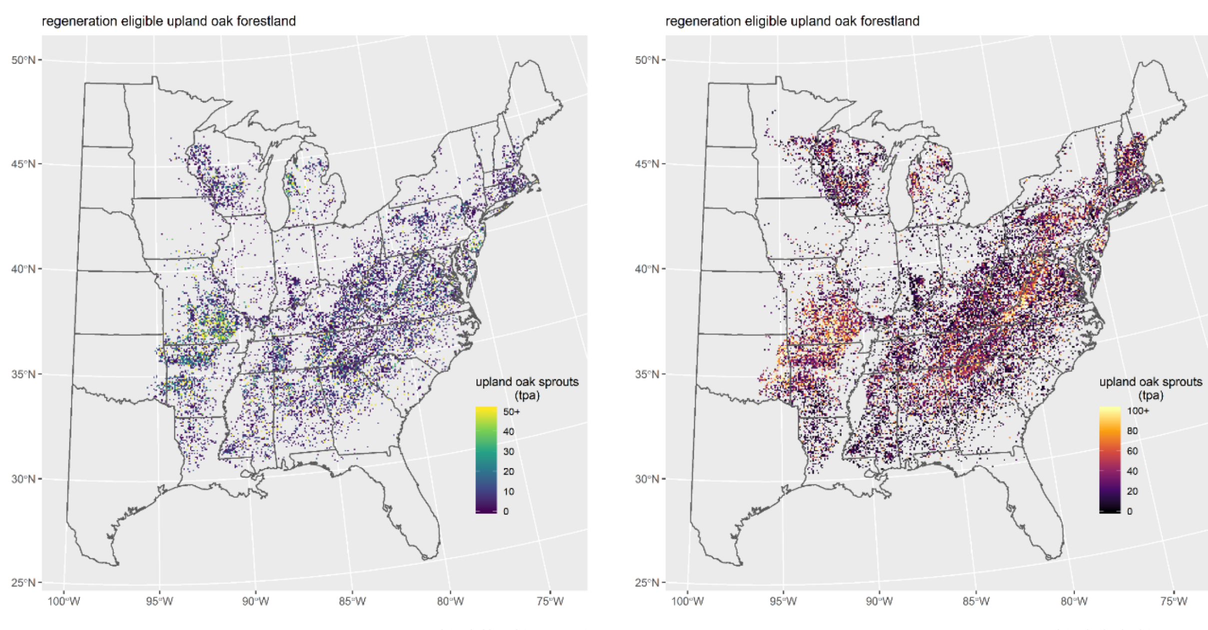


Figure 26. White and upland oak potential sprout abundance, local scale, potential trees per acre (dbh ≥ 3 in.), white oak [L], upland oak [R], eastern US regeneration eligible upland oak forestland, 2017. Each cell represents ≈12,000 acres.

[1] Estimates based on models used by USFS Forest Vegetation Simulator, Southern Variant (Keyser 2008)

Table 5. Reproduction abundance by type, species, and ecological section, eastern US regeneration eligible upland oak forestland, 2017.

		Saplings			Seedlings			Potential Sprouts	
SCT_CD	Section Name	All species	Upland oaks	White oak	All species	Upland oaks	White oak	Upland oaks	White oak
		... trees per acre ...							
211E	St. Lawrence and Champlain Valley	404	38	2	2,203	265	38	25	1
211F	Northern Glaciated Allegheny Plateau	209	9	1	2,540	214	35	33	4
211G	Northern Unglaciated Allegheny Plateau	217	19	9	2,112	217	45	30	4
211I	Catskill Mountains	247	4	0	2,440	97	12	30	2
212H	Northern Lower Peninsula	306	28	9	2,650	591	279	39	9
212K	Western Superior Uplands	390	19	1	2,967	168	25	23	1
212Q	North Central Wisconsin Uplands	318	13	2	3,068	105	36	29	5
212T	Northern Green Bay Lobe	358	23	1	2,638	176	13	18	0
212X	Northern Highlands	447	17	1	4,003	229	9	22	0
221A	Lower New England	256	19	4	1,650	165	60	36	4
221B	Hudson Valley	203	11	4	1,550	152	28	24	2
221D	Northern Appalachian Piedmont	180	12	5	1,218	223	106	26	6
221E	Southern Unglaciated Allegheny Plateau	248	16	5	2,343	301	97	25	5
221F	Western Glaciated Allegheny Plateau	194	8	0	1,937	67	9	14	1
221H	Northern Cumberland Plateau	374	17	5	3,192	418	144	32	10
221J	Central Ridge and Valley	321	23	7	3,126	346	90	31	6
222H	Central Till Plains-Beech-Maple	245	5	0	2,740	113	33	15	1
222I	Erie and Ontario Lake Plain	271	16	0	2,377	80	28	27	1
222J	South Central Great Lakes	237	18	6	2,141	190	70	32	6
222K	Southwestern Great Lakes Morainal	166	13	6	1,555	218	100	22	6
222L	North Central U.S. Driftless and Escarpment	252	10	4	1,455	63	26	26	5
222M	Minnesota and Northeast Iowa Morainal-Oak Savannah	295	5	1	2,884	44	3	17	2
222R	Wisconsin Central Sands	345	48	15	2,370	535	147	22	7
222U	Lake Whittlesey Glaciolacustrine Plain	293	7	0	2,227	50	20	13	4
223A	Ozark Highlands	296	42	18	2,603	530	257	64	20
223B	Interior Low Plateau-Transition Hills	236	9	4	2,546	266	98	23	3
223D	Interior Low Plateau-Shawnee Hills	281	23	8	3,322	402	199	20	4
223E	Interior Low Plateau-Highland Rim	283	13	3	2,499	267	98	27	7
223F	Interior Low Plateau-Bluegrass	232	21	2	2,625	173	49	22	2
223G	Central Till Plains-Oak Hickory	217	7	1	2,280	116	36	17	6
231A	Southern Appalachian Piedmont	371	26	10	2,280	262	131	26	9
231B	Coastal Plains-Middle	426	33	14	1,669	240	102	23	7
231C	Southern Cumberland Plateau	358	26	12	1,700	195	78	39	10
231D	Southern Ridge and Valley	374	30	10	1,830	240	62	40	6
231E	Mid Coastal Plains-Western	426	30	13	1,529	149	48	16	5
231G	Arkansas Valley	295	36	6	1,951	427	60	48	4
231H	Coastal Plains-Loess	390	32	16	1,441	224	102	22	7
231I	Central Appalachian Piedmont	438	34	15	2,574	414	238	30	11
232A	Northern Atlantic Coastal Plain	182	17	7	903	72	20	41	15

		Saplings			Seedlings			Potential Sprouts	
SCT_CD	Section Name	All species	Upland oaks	White oak	All species	Upland oaks	White oak	Upland oaks	White oak
		... trees per acre ...							
232B	Gulf Coastal Plains and Flatwoods	338	21	7	1,469	132	20	11	3
232C	Atlantic Coastal Flatwoods	410	17	9	2,079	83	36	13	5
232F	Coastal Plains and Flatwoods-Western Gulf	315	24	9	1,382	154	47	18	4
232H	Middle Atlantic Coastal Plains and Flatwoods	423	17	8	1,268	116	57	24	7
232I	Northern Atlantic Coastal Flatwoods	445	16	8	1,161	71	43	9	4
232J	Southern Atlantic Coastal Plains and Flatwoods	336	25	4	1,726	131	31	18	4
232L	Gulf Coastal Lowlands	374	7	3	1,067	92	26	3	1
234A	Southern Mississippi Alluvial Plain	265	15	5	962	70	37	17	1
234D	White and Black River Alluvial Plains	328	30	15	1,946	309	130	17	4
234E	Arkansas Alluvial Plains	321	10	3	970	189	50	23	4
251C	Central Dissected Till Plains	211	8	3	2,079	160	86	24	7
251D	Central Till Plains and Grand Prairies	247	16	2	2,182	359	278	15	5
251E	Osage Plains	195	7	1	2,526	209	20	31	1
M211B	New England Piedmont	358	14	0	2,289	136	8	27	1
M221A	Northern Ridge and Valley	227	19	3	1,442	249	49	51	5
M221B	Allegheny Mountains	254	11	2	1,949	234	45	34	4
M221C	Northern Cumberland Mountains	358	16	2	2,273	254	40	28	4
M221D	Blue Ridge Mountains	243	14	2	1,671	275	41	40	3
M223A	Boston Mountains	318	26	8	2,667	403	112	43	14
M231A	Ouachita Mountains	349	49	18	1,894	383	121	43	13
	Area-weighted Average	310	23	8	2,110	271	98	32	7

TASK 4: COMPARE MID- AND UNDERSTORY POPULATION TO CANOPY OF REGENERATION ELIGIBLE AREAS

Results from Task 3 indicate that the current oak domination of forests that occurs in many places is a product of relatively few (numerically), but large oak trees. Although white oaks become increasingly prevalent as large trees, saplings are scarce. Numerically, white (**Figure 27**) and upland oaks decrease with increasing size (diameter), which is an outcome generally expected (**Figure 28**). However, both white (**Figure 29**) and upland oak relative abundance increases with diameter class, and, in many cases, upland oak is ≳ 50% of stems per diameter class over 15 in. in several ecological sections (**Figure 30**).

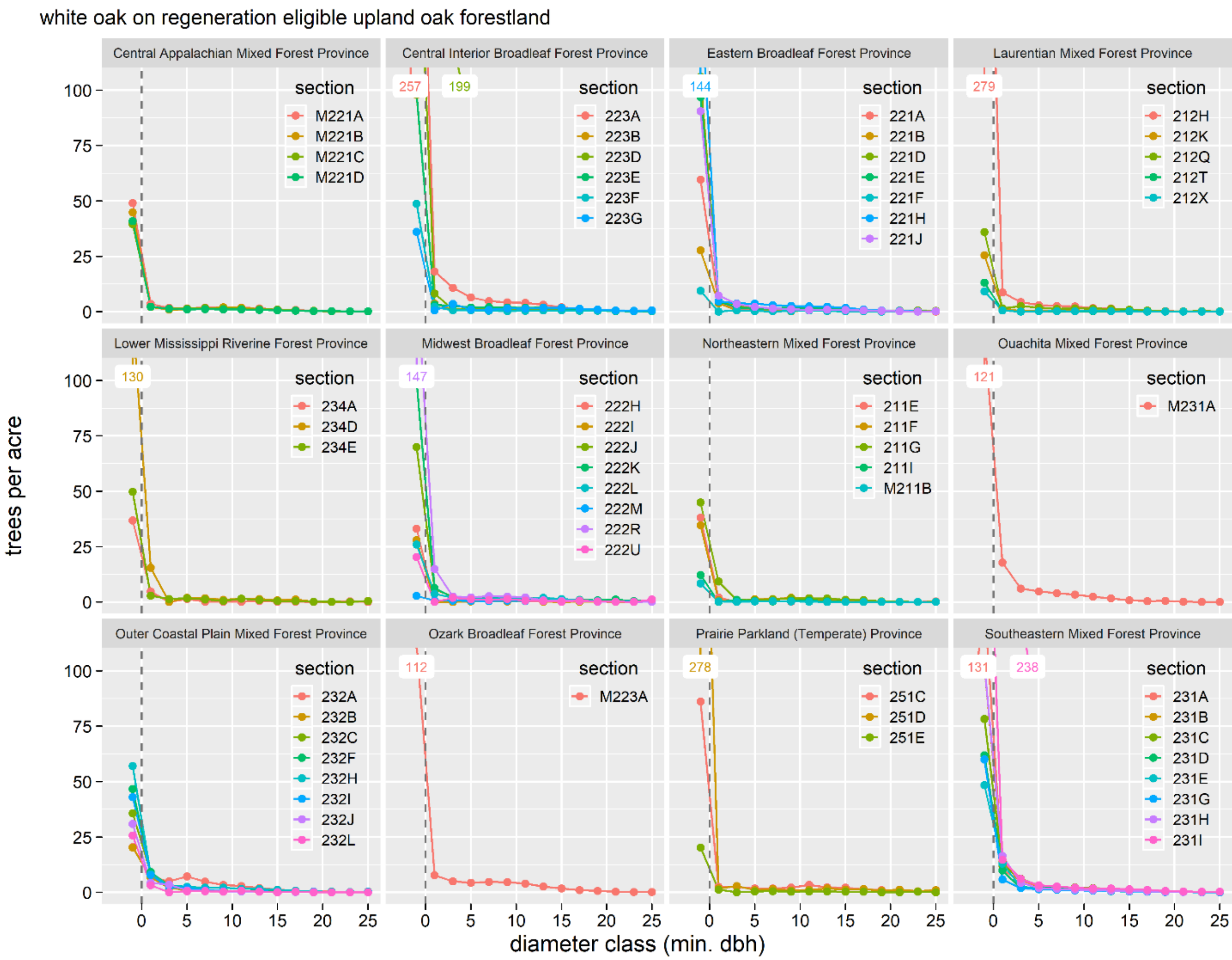


Figure 27. White oak abundance by diameter class and ecological section, stems per acre, eastern US regeneration eligible upland oak forestland, 2017. Data left of the broken vertical line (x=0) represent seedlings. Two-inch diameter classes were used, starting at one-inch and classes are labeled according to the minimum diameter included. All trees with dbh ≥ 25 in. are included in the 25 in. class. Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

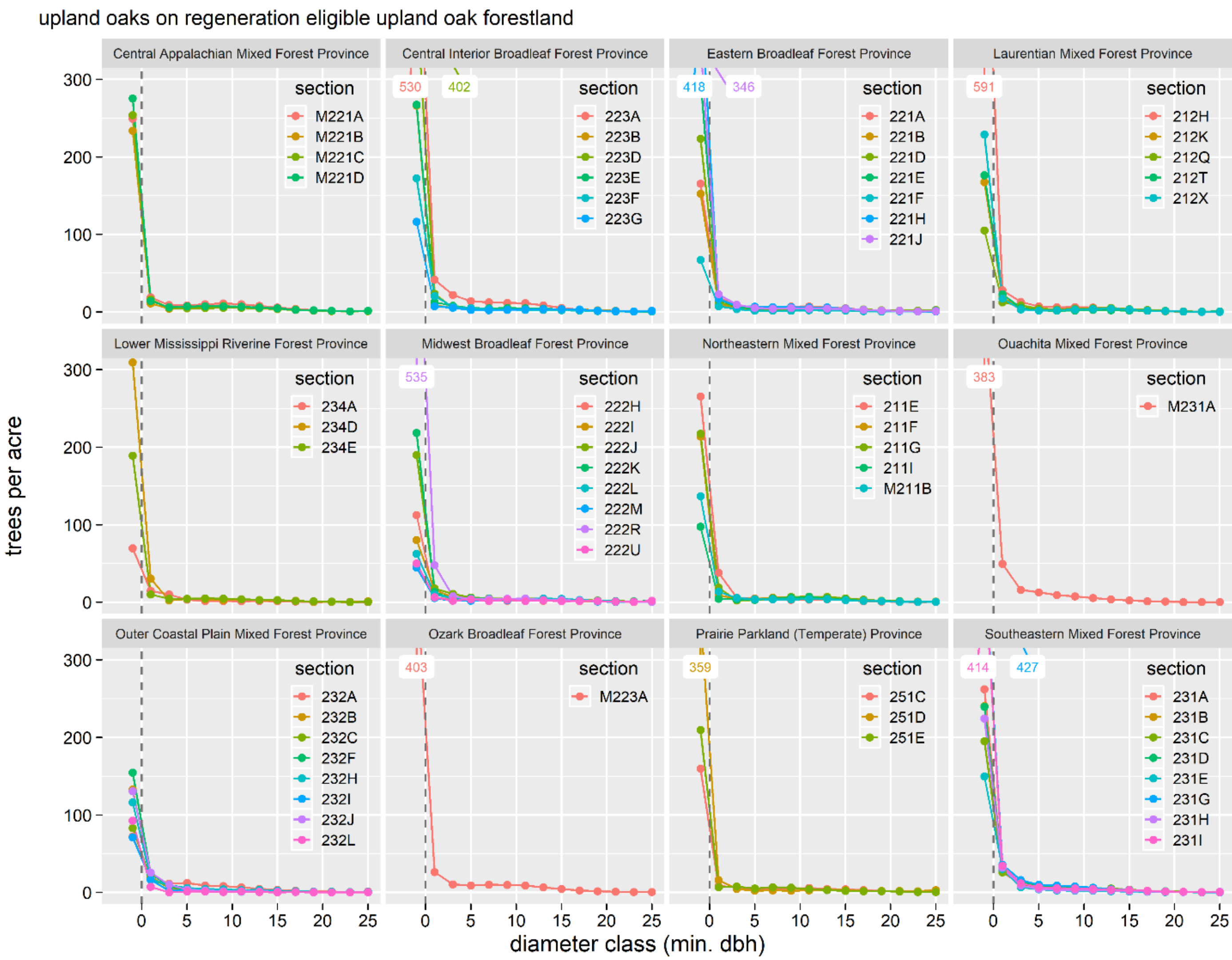


Figure 28. Upland oak abundance by diameter class and ecological section, trees per acre, eastern US regeneration eligible upland oak forestland, 2017. Data left of the broken vertical line (x=0) represent seedlings. Two-inch diameter classes were used, starting at one-inch and classes are labeled according to the minimum diameter included. All trees with dbh ≥ 25 in. are included in the 25 in. class. Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

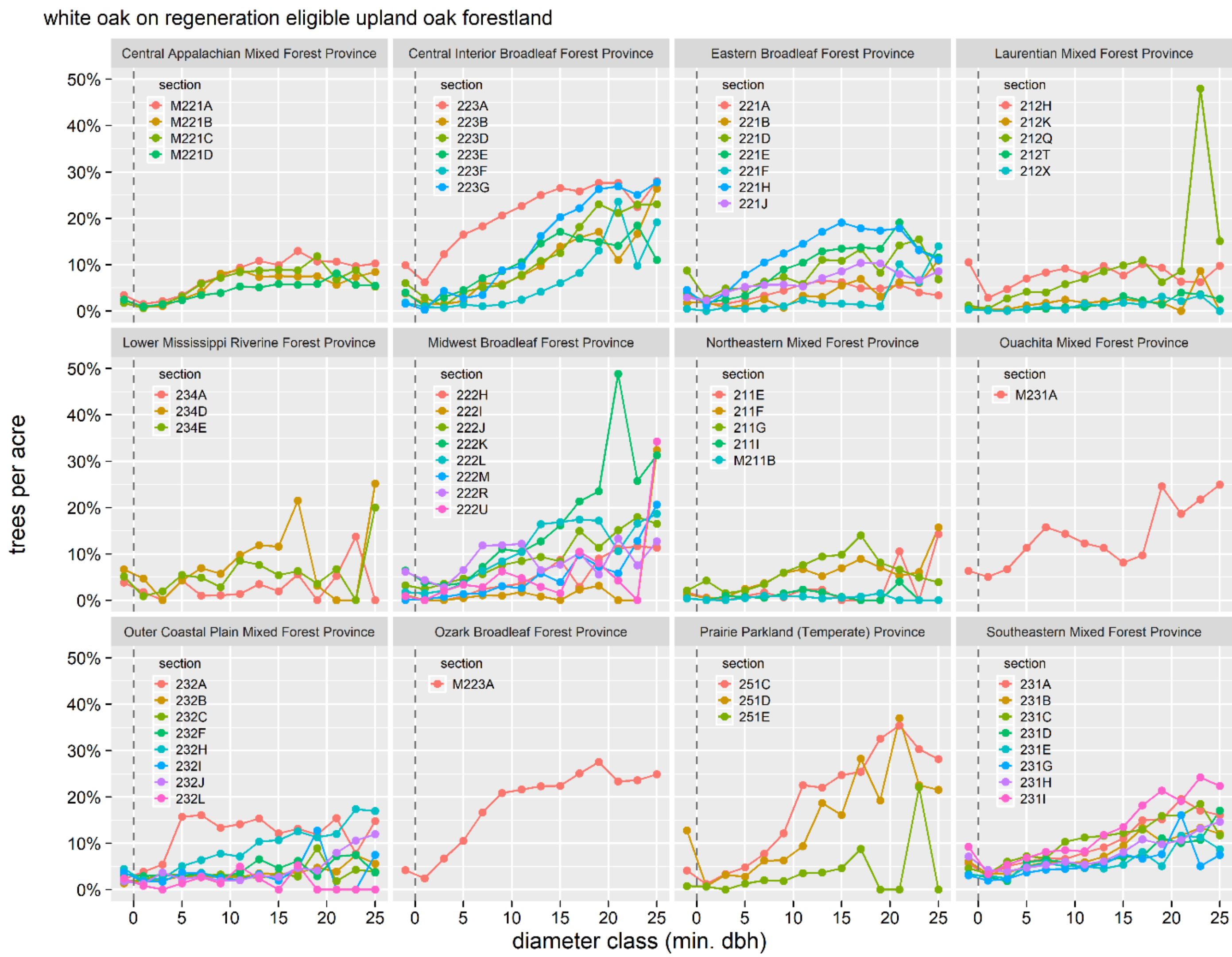


Figure 29. White oak relative abundance by diameter class and ecological section, % trees per acre, eastern US regeneration eligible upland oak forestland, 2017. Data left of the broken vertical line (x=0) represent seedlings. Two-inch diameter classes were used, starting at one-inch and classes are labeled according to the minimum diameter included. All trees with dbh ≥ 25 in. are included in the 25 in. class. Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

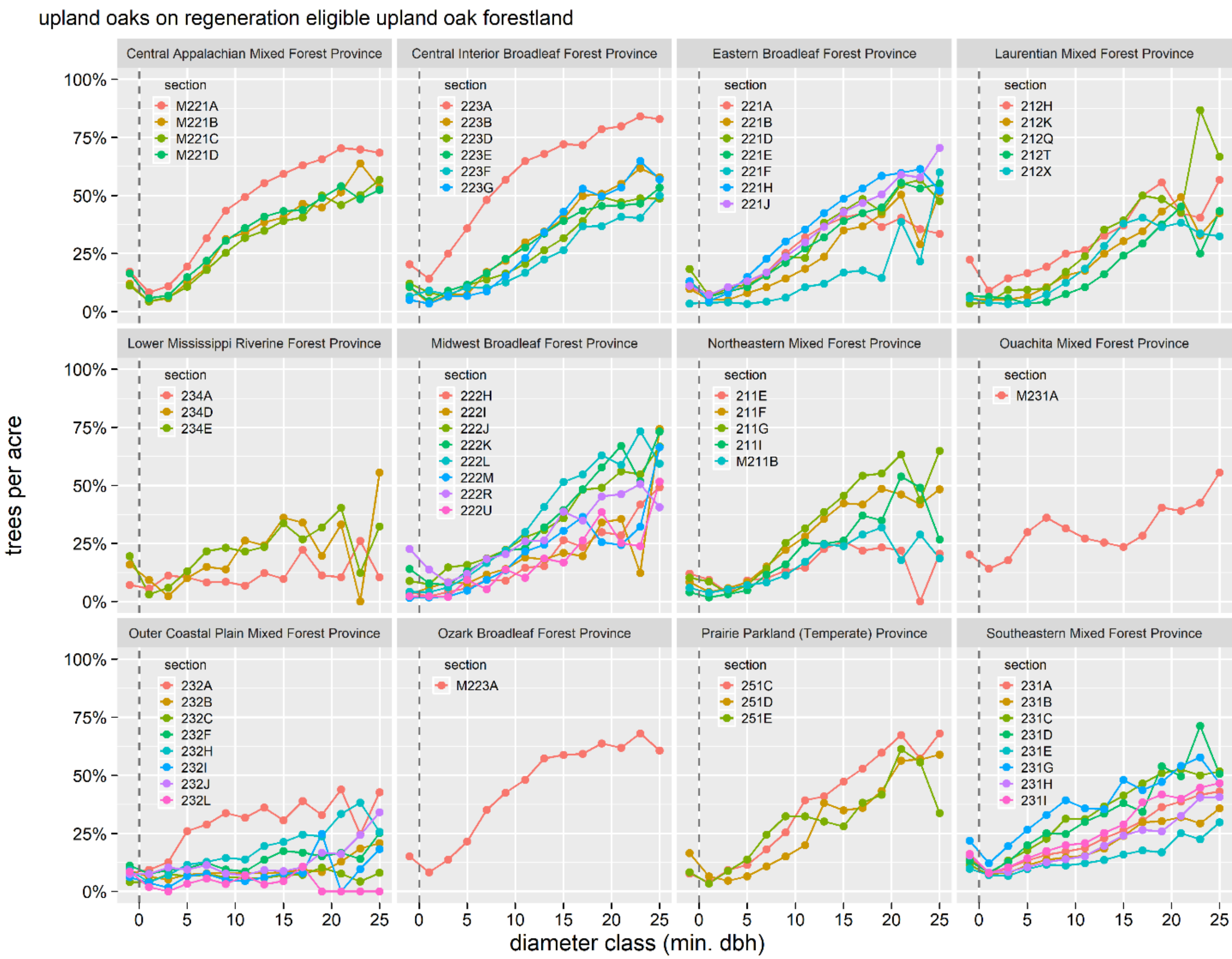


Figure 30. Upland oak relative abundance by diameter class and ecological section , % trees per acre, eastern US regeneration eligible upland oak forestland, 2017. Data left of the broken vertical line (x=0) represent seedlings. Two-inch diameter classes were used, starting at one-inch and classes are labeled according to the minimum diameter included. All trees with dbh ≥ 25 in. are included in the 25 in. class. Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

Across many ecological sections white (**Figure 31**) and upland oaks (**Figure 32**) also exhibit considerable decreases in mean abundance from the seedling layer to overtopped canopy positions, which is to be expected, and typically further decrease between the overtopped and intermediate canopy positions. Oaks are usually as abundant, but often more abundant as a codominant compared to other canopy positions. There is also a pattern of increasing white (**Figure 33**) and upland oak (**Figure 34**) relative abundance with increasing canopy position as well. Across the range, upland oaks average 8 and 14% of overtopped and intermediate trees per acre, respectively, but 25% of stems in the upper canopy (codominant and dominant). White oak averages about 8 trees per acre or 7% of all upper canopy trees across the range.

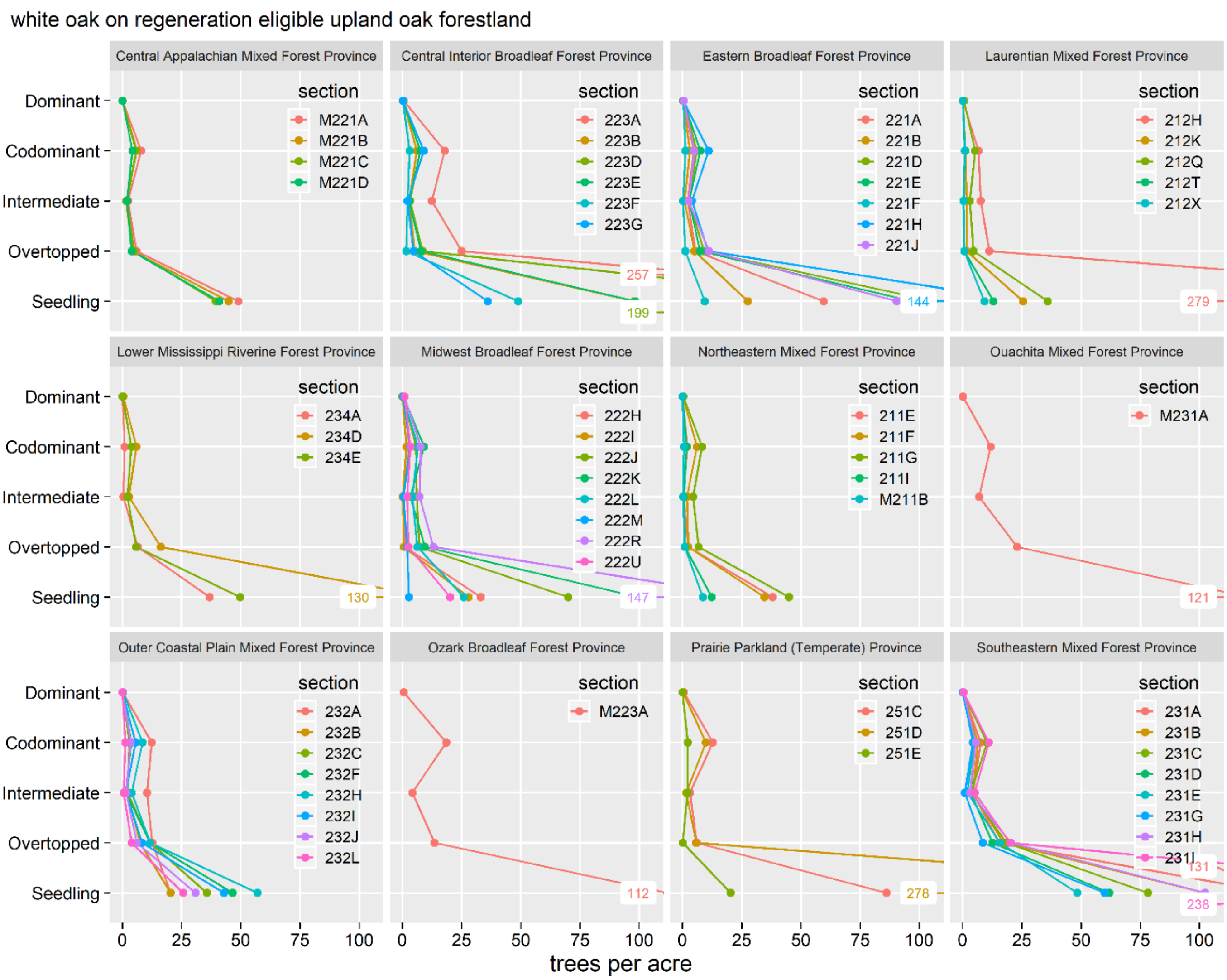


Figure 31. White oak abundance by canopy position and ecological section, trees per acre, eastern US regeneration eligible upland oak forestland, 2017. Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

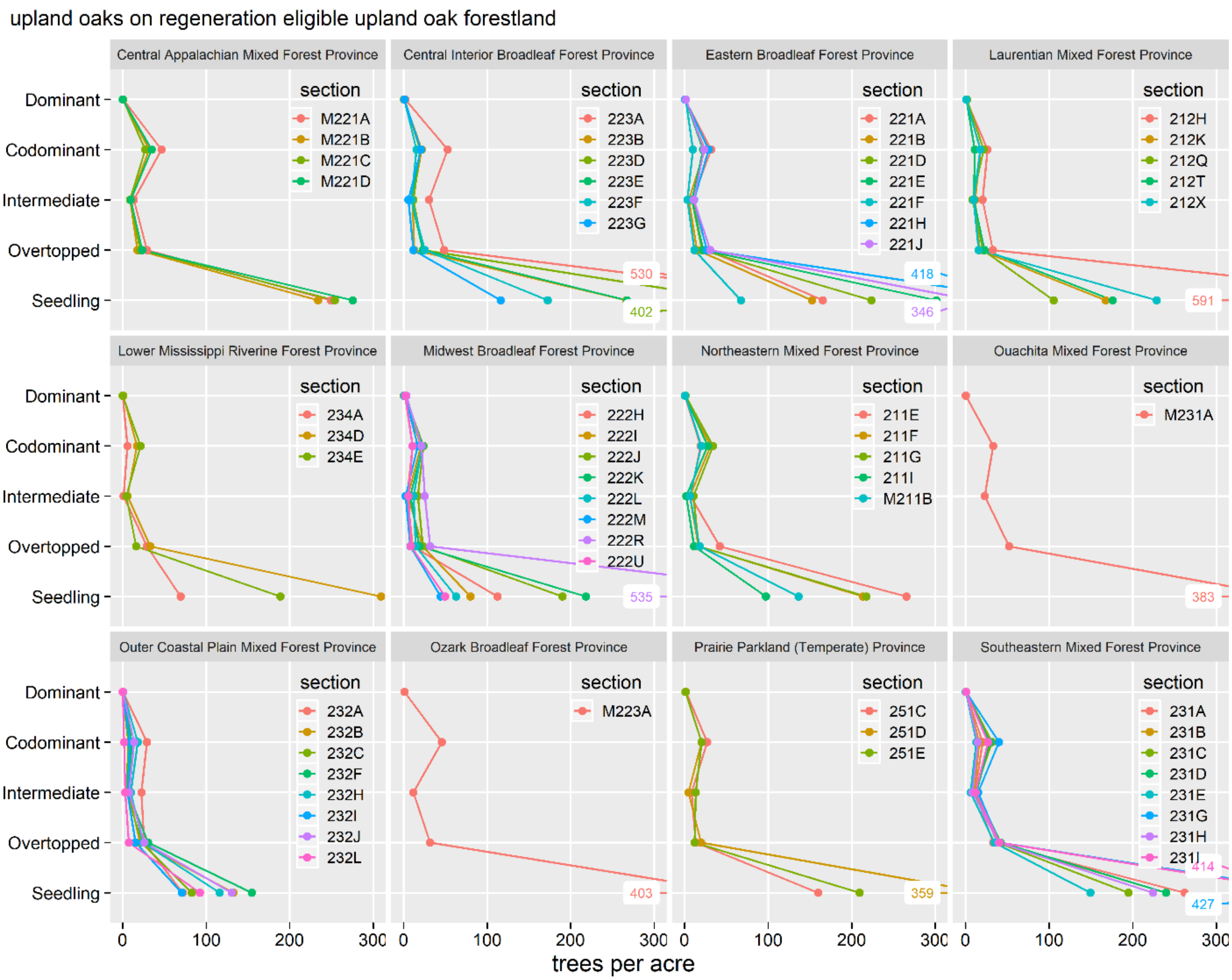


Figure 32. Upland oak abundance by canopy position and ecological section, trees per acre, eastern US regeneration eligible upland oak forestland, 2017. Panel positions and colors within a panel correspond to the areas highlighted in Figure 4.

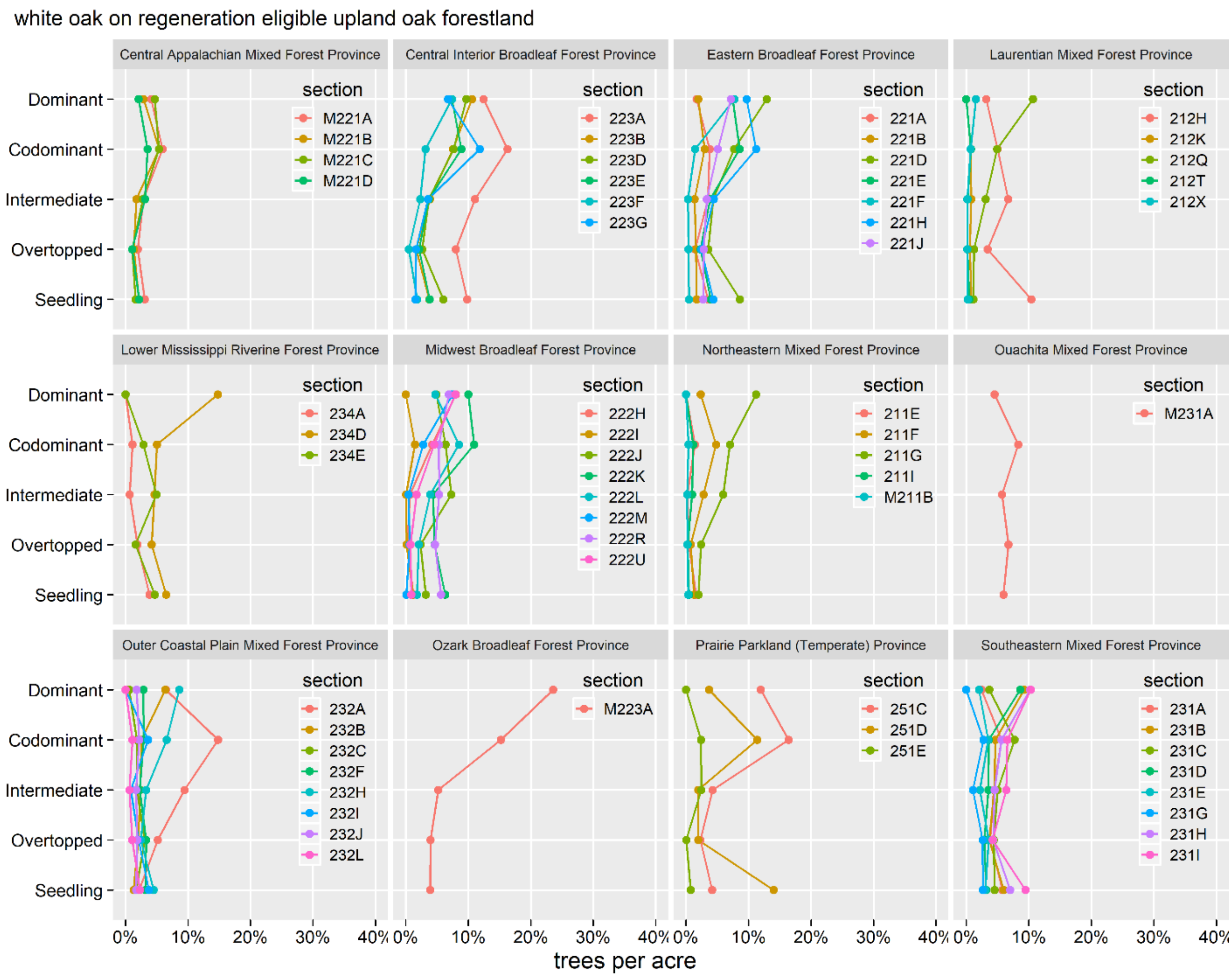


Figure 33. White oak relative abundance by canopy position and ecological section, % trees per acre, eastern US regeneration eligible upland oak forestland, 2017. Panel positions and colors within a panel correspond to the areas highlighted in Figure 2.

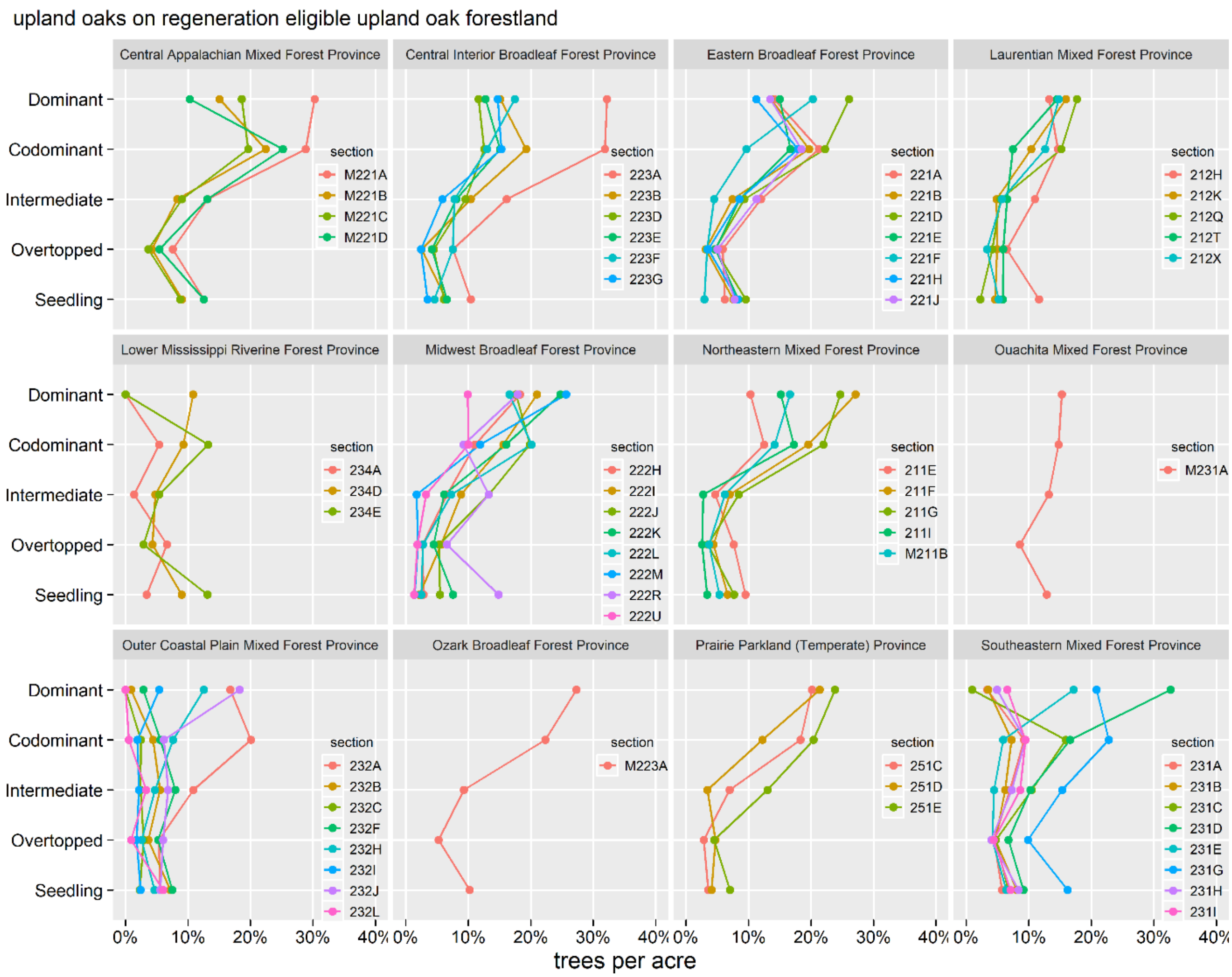


Figure 34. Upland oak relative abundance by canopy position and ecological section, % trees per acre, eastern US regeneration eligible upland oak forestland, 2017. Panel positions and colors within a panel correspond to the areas highlighted in Figure 2.

In all but one section, Minnesota & NE Iowa Morainal-Oak Savannah [222M], white oak abundance is higher for seedling than the upper canopy (Figure 35), but the pattern is reversed for relative abundance (Figure 36). Upland oak seedlings also tend to be numerically greater than the upper canopy upland oaks but not in relative abundance (Figure 37, Figure 38).

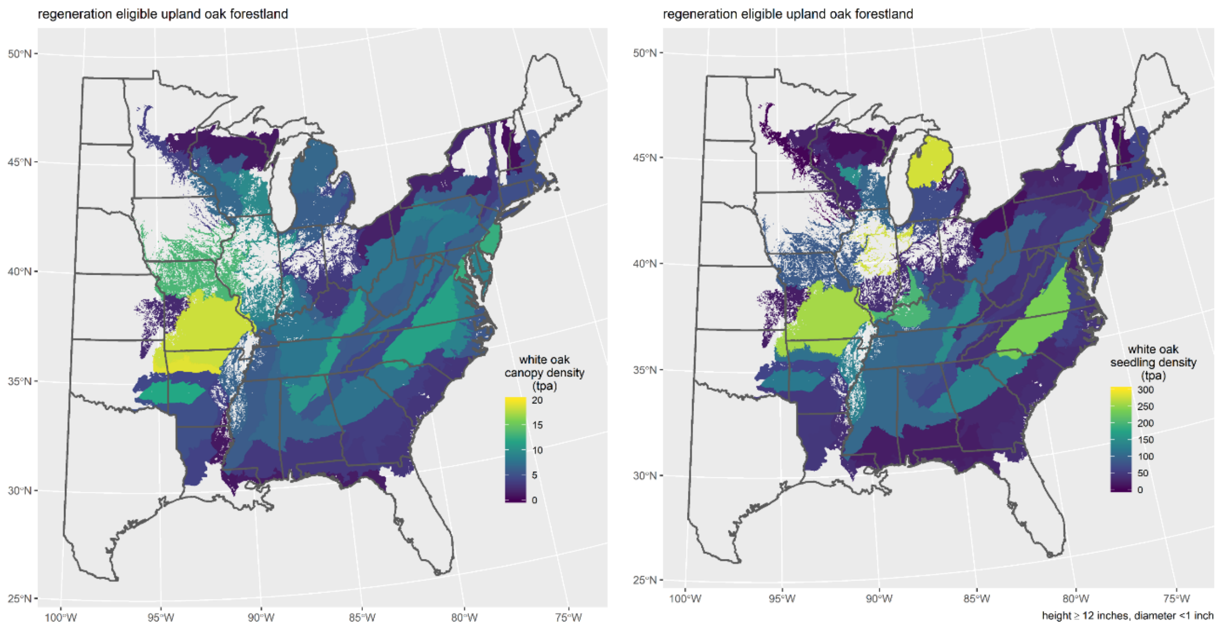


Figure 35. White oak upper canopy and seedling abundance by ecological section, trees per acre, upper canopy (dominant or codominant) [L], seedlings (dbh < 1 in.; height ≥ 12 in.) [R], eastern US regeneration eligible upland oak forestland, 2017.

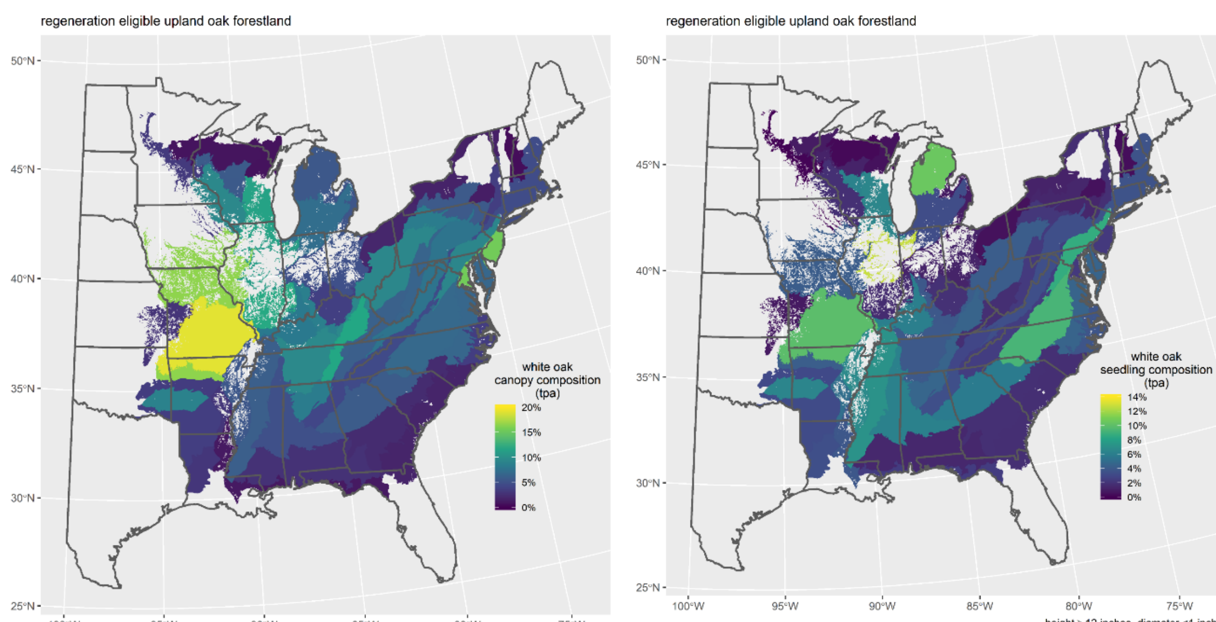


Figure 36. White oak upper canopy and seedling relative abundance by ecological section, % trees per acre, upper canopy (dominant or codominant) [L], seedlings (dbh < 1 in.; height ≥ 12 in.) [R], eastern US regeneration eligible upland oak forestland, 2017.

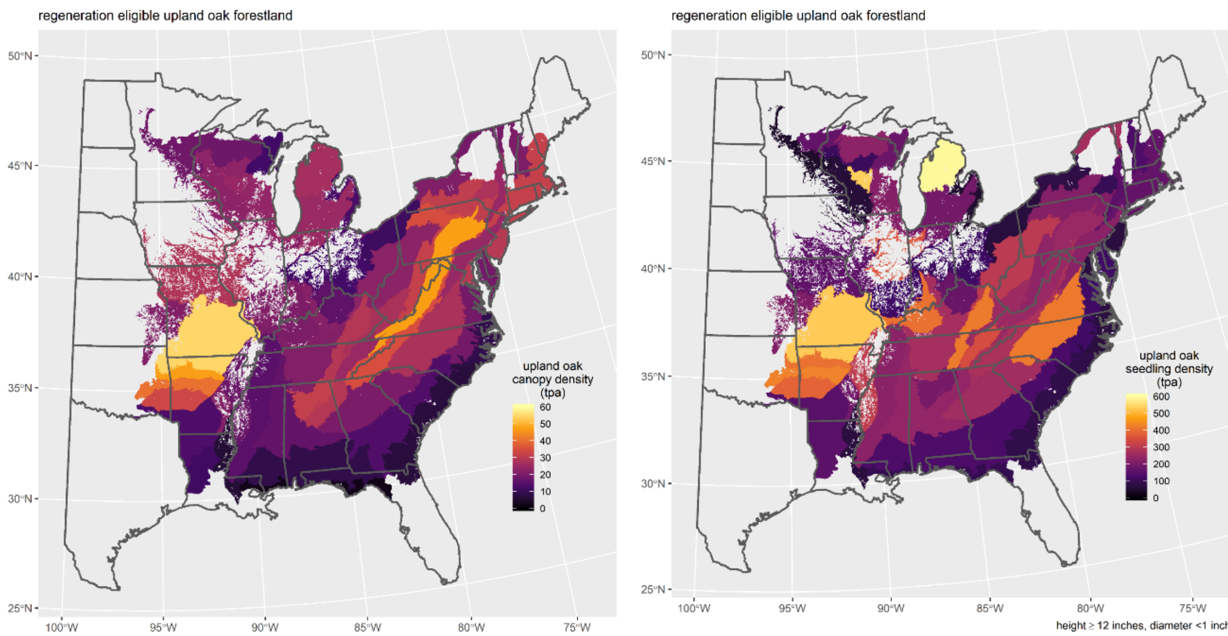


Figure 37. Upland oak upper canopy and seedling abundance by ecological section, trees per acre, upper canopy (dominant or codominant) [L], seedlings (dbh < 1 in.; height ≥ 12 in.) [R], eastern US regeneration eligible upland oak forestland, 2017.

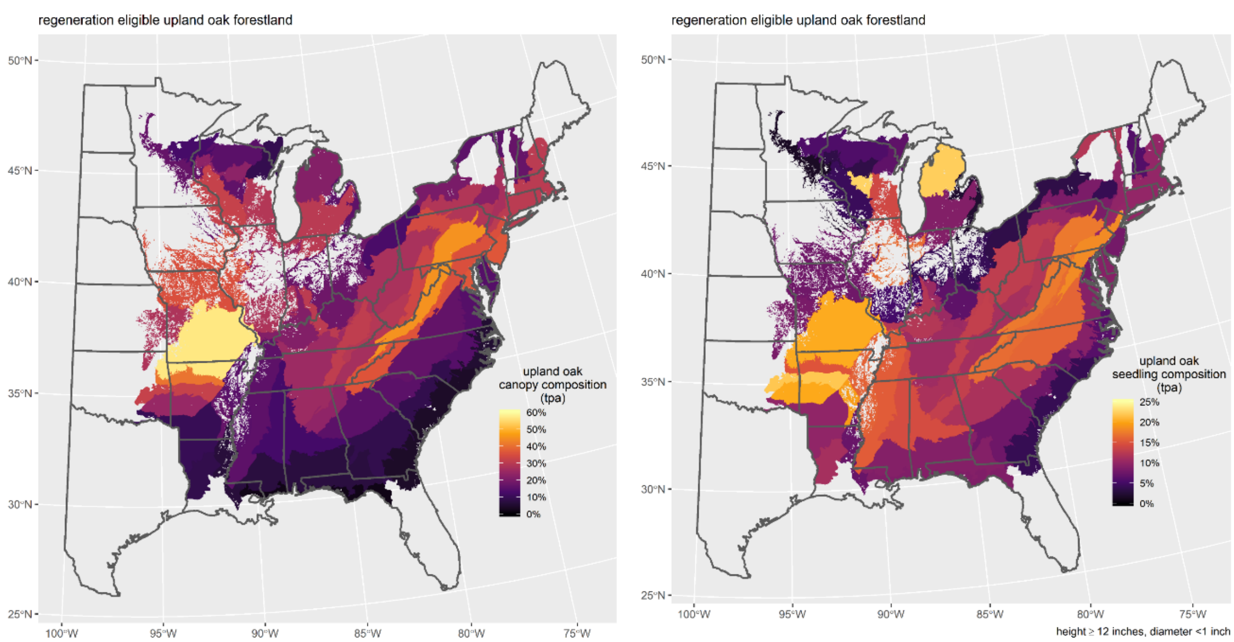


Figure 38. Upland oak upper canopy and seedling relative abundance by ecological section, % trees per acre, upper canopy (dominant or codominant) [L], seedlings (dbh < 1 in.; height ≥ 12 in.) [R], eastern US regeneration eligible upland oak forestland, 2017.

TASK 5: HIGHLIGHT AREAS OF REGENERATION CONCERN

In many places, the next generation of white oak in mature stands is not clearly established and no section is immune to regeneration concerns. For example, while the Ozark Highlands [223A] has the 2nd lowest proportion of regeneration eligible white oak acres without seedlings ('only' 37%), saplings are overwhelmingly absent (81% of acres). This highlights that regeneration concerns can be different in kind, those where bottlenecks appear in seedling establishment vs those where bottlenecks appear during canopy recruitment. An estimated 60% of regeneration eligible white oak acres have no white oak seedlings present and about 87% have no white oak saplings present (Figure 39).

Limited canopy recruitment of saplings is a concern across the range, especially for white oak (Figure 40) as saplings were absent on no fewer than 72% of regeneration eligible white oak acres in any ecological section (Table 6). Among the larger sections (≥ 1 million regeneration eligible acres), white oak establishment concerns were relatively higher (≳ 75% seedling-less acres) in the Driftless and Escarpment [222L], Gulf Coastal Plains and Flatwoods [232B], and Central Appalachians [M221A, B, D]. In contrast, establishment concerns were relatively lower (≤ 50% seedling-less acres) in the Ozark Highlands [223A], Shawnee Hills [223D], Central Appalachian Piedmont [231I], Ouachita Mountains [M231A], and Northern Lower Peninsula [212H].

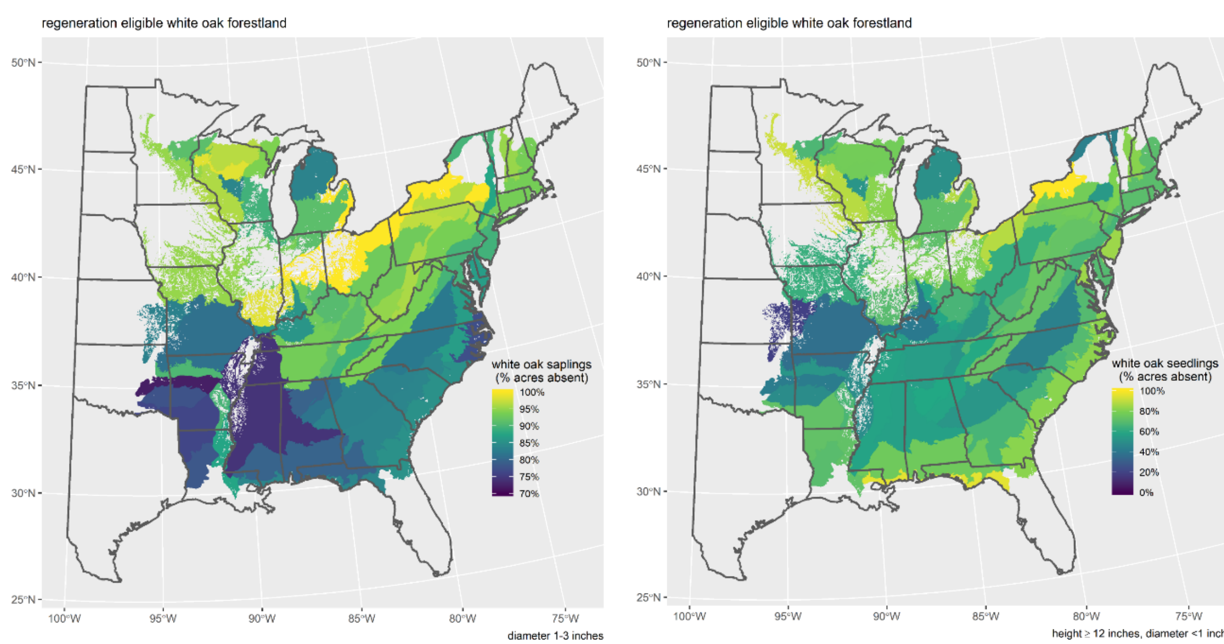
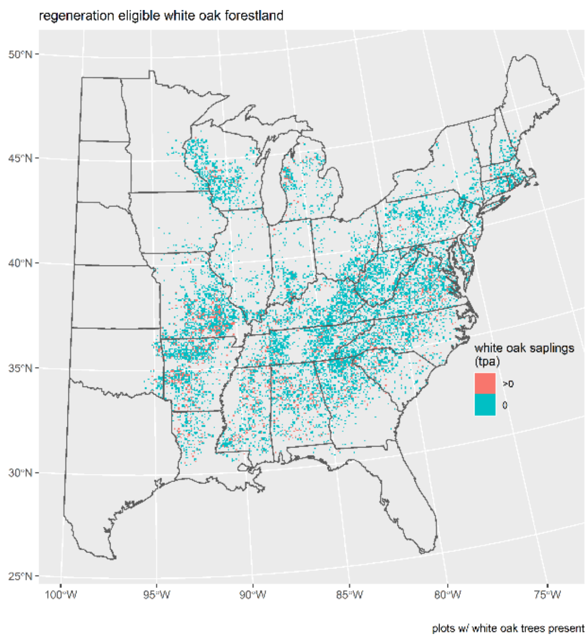


Figure 39. White oak reproduction absence by type and ecological section, % forestland with white oak trees present but, saplings absent (dbh 1-3 in.) [L], seedlings absent (dbh < 1 in.; height ≥ 12 in.) [R], eastern US regeneration eligible white oak forestland, 2017.



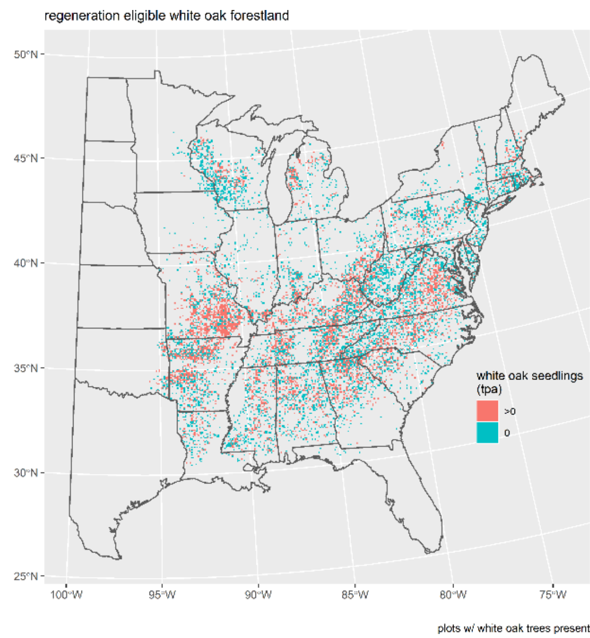


Figure 40. White oak reproduction presence/absence by type, local scale, saplings (dbh 1-3 in.) [L], seedlings (dbh < 1 in.; height ≥ 12 in.) [R], eastern US regeneration eligible white oak forestland, 2017. Each cell represents ≈ 12,000 acres.

As with white oak, upland oak regeneration concerns are pervasive. An estimated 71 million acres, or about 54% of regeneration eligible upland oak forestland had upland oaks present as trees but absent as seedlings. Only 16 ecological sections had upland oak seedlings present on a majority (≥ 51%) of acres (Figure 41). Upland oak establishment concerns were relatively higher (≳ 75% seedling-less acres) on 16 ecological sections with the Driftless and Escarpment [222L], Atlantic Coastal Flatwoods [232C], Middle Atlantic Coastal Plains and Flatwoods [232H], Northern Appalachian Piedmont [221D], and South Central Great Lakes [222J] among the larger sections (≥ 1 million regeneration eligible acres).

Limited canopy recruitment of upland oak saplings is also of major concern across the range (Figure 42). Upland oak saplings were absent on over 109 million regeneration eligible acres (83%) and no fewer than 69% of acres in any ecological section.

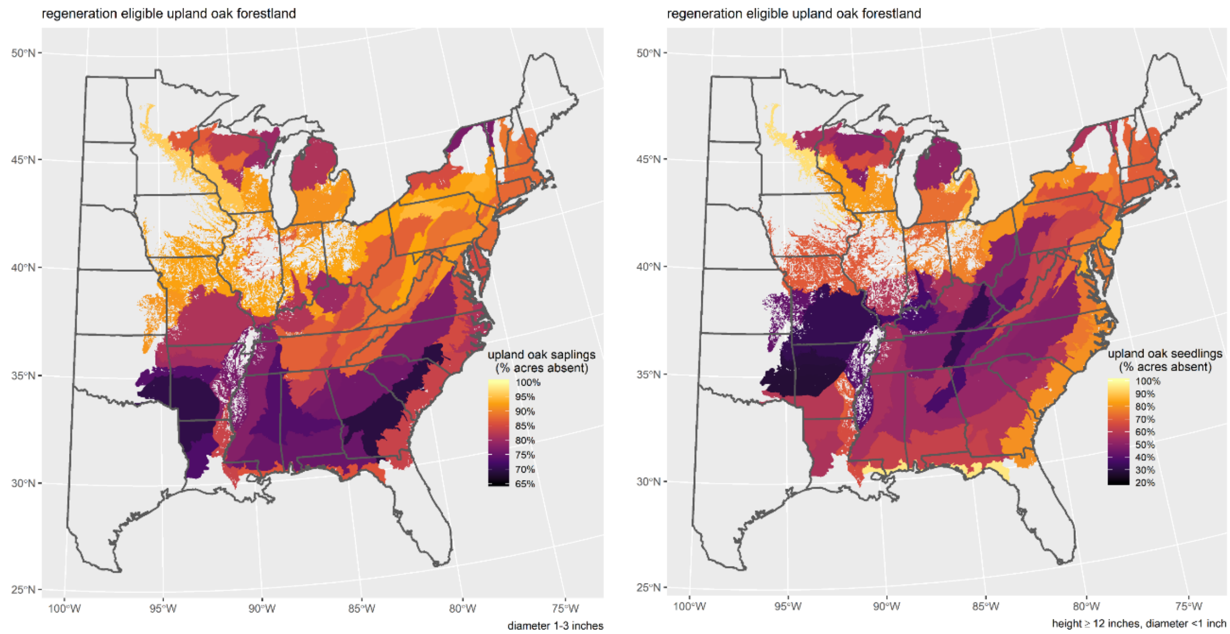


Figure 41. Upland oak reproduction absence by type and ecological section, % forestland with upland oak trees present but, saplings absent (dbh 1-3 in.) [L], seedlings absent (dbh < 1 in.; height ≥ 12 in.) [R], eastern US regeneration eligible upland oak forestland, 2017.

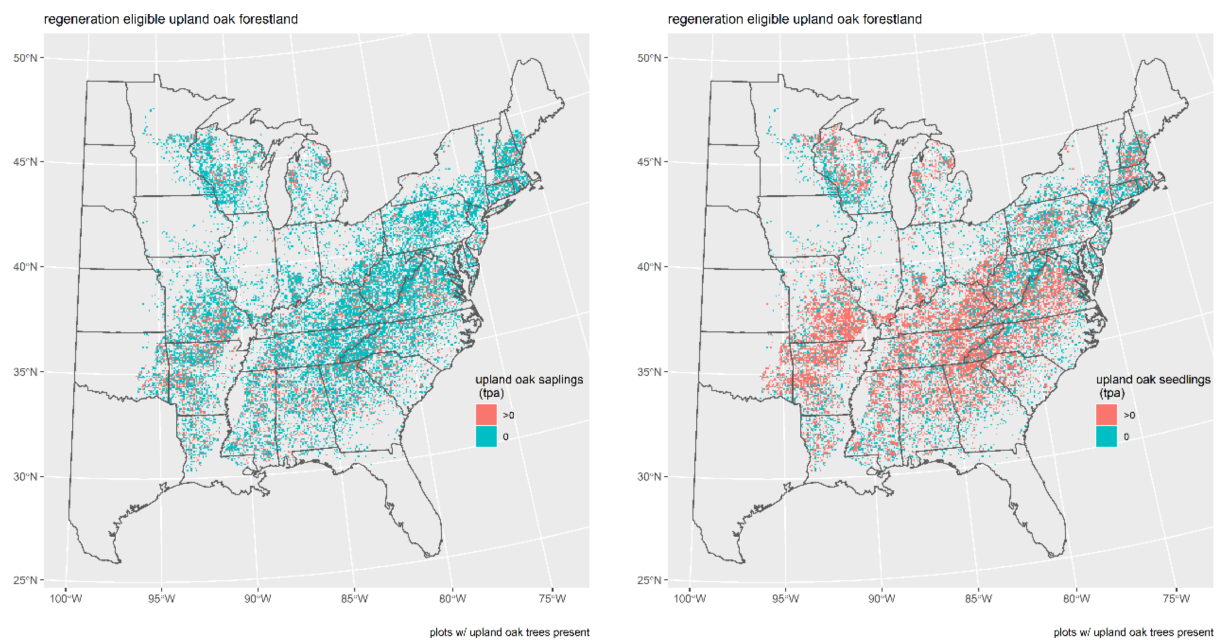


Figure 42. Upland oak reproduction presence/absence by type, local scale, saplings (dbh 1-3 in.) [L], seedlings (dbh < 1 in.; height ≥ 12 in.) [R], eastern US regeneration eligible upland oak, 2017. Each cell represents ≈ 12,000 acres.

Table 6. Area of reproduction absence by type, species, and ecological section, eastern US regeneration eligible forestland, 2017.

		Regeneration eligible forestland		Saplings absent		Seedlings absent	
SCT_CD	Section Name	Upland oak	White oak	Upland oak	White oak	Upland oak	White oak
		… acres (millions) …		… % species total …			
211E	St. Lawrence and Champlain Valley	0.24	0.08	77%	90%	57%	44%
211F	Northern Glaciated Allegheny Plateau	2.02	0.93	93%	96%	67%	78%
211G	Northern Unglaciated Allegheny Plateau	1.65	0.81	94%	97%	70%	76%
211I	Catskill Mountains	0.59	0.07	94%	100%	78%	54%
212H	Northern Lower Peninsula	2.13	1.10	81%	83%	51%	50%
212K	Western Superior Uplands	0.68	0.12	87%	91%	56%	67%
212Q	North Central Wisconsin Uplands	0.48	0.27	88%	99%	67%	77%
212T	Northern Green Bay Lobe	0.46	0.07	80%	94%	64%	77%
212X	Northern Highlands	0.96	0.12	83%	97%	50%	78%
221A	Lower New England	5.44	2.85	88%	94%	70%	70%
221B	Hudson Valley	0.90	0.39	92%	88%	74%	80%
221D	Northern Appalachian Piedmont	1.25	0.70	92%	90%	74%	66%
221E	Southern Unglaciated Allegheny Plateau	8.00	5.28	87%	93%	49%	62%
221F	Western Glaciated Allegheny Plateau	0.96	0.26	93%	100%	81%	88%
221H	Northern Cumberland Plateau	4.35	3.45	85%	91%	32%	52%
221J	Central Ridge and Valley	1.43	0.92	86%	89%	40%	60%
222H	Central Till Plains-Beech-Maple	0.86	0.29	93%	100%	77%	80%
222I	Erie and Ontario Lake Plain	0.36	0.10	85%	100%	80%	100%
222J	South Central Great Lakes	1.43	0.75	91%	91%	74%	71%
222K	Southwestern Great Lakes Morainal	0.70	0.44	92%	89%	81%	82%
222L	North Central U.S. Driftless and Escarpment	2.06	1.35	95%	96%	82%	89%
222M	Minnesota and Northeast Iowa Morainal-Oak Savannah	0.37	0.09	96%	95%	94%	92%
222R	Wisconsin Central Sands	0.47	0.29	81%	84%	49%	52%
222U	Lake Whittlesey Glaciolacustrine Plain	0.31	0.13	92%	100%	88%	88%
223A	Ozark Highlands	10.00	8.00	81%	81%	32%	37%
223B	Interior Low Plateau-Transition Hills	1.18	0.78	92%	93%	46%	59%
223D	Interior Low Plateau-Shawnee Hills	2.49	1.79	82%	86%	37%	40%
223E	Interior Low Plateau-Highland Rim	4.43	2.80	87%	93%	47%	56%
223F	Interior Low Plateau-Bluegrass	1.20	0.35	80%	91%	57%	66%
223G	Central Till Plains-Oak Hickory	0.81	0.51	93%	99%	58%	70%

		Regeneration eligible forestland		Saplings absent		Seedlings absent	
SCT_CD	Section Name	Upland oak	White oak	Upland oak	White oak	Upland oak	White oak
		… acres (millions) …			… % species total …		
231A	Southern Appalachian Piedmont	5.98	4.21	76%	83%	52%	53%
231B	Coastal Plains-Middle	4.57	2.98	73%	74%	54%	57%
231C	Southern Cumberland Plateau	1.86	1.32	83%	80%	56%	60%
231D	Southern Ridge and Valley	1.69	1.03	76%	82%	37%	58%
231E	Mid Coastal Plains-Western	3.67	2.10	70%	76%	59%	72%
231G	Arkansas Valley	1.17	0.41	74%	72%	28%	42%
231H	Coastal Plains-Loess	3.66	2.32	78%	74%	56%	58%
231I	Central Appalachian Piedmont	6.43	5.19	77%	82%	49%	44%
232A	Northern Atlantic Coastal Plain	0.90	0.64	88%	89%	85%	85%
232B	Gulf Coastal Plains and Flatwoods	4.21	1.66	75%	80%	63%	76%
232C	Atlantic Coastal Flatwoods	0.99	0.42	84%	85%	80%	82%
232F	Coastal Plains and Flatwoods-Western Gulf	1.49	0.76	73%	78%	57%	70%
232H	Middle Atlantic Coastal Plains and Flatwoods	2.24	1.67	85%	87%	75%	69%
232I	Northern Atlantic Coastal Flatwoods	0.41	0.24	81%	77%	79%	83%
232J	Southern Atlantic Coastal Plains and Flatwoods	2.22	0.72	69%	84%	59%	66%
232L	Gulf Coastal Lowlands	0.15	0.06	86%	84%	96%	96%
234A	Southern Mississippi Alluvial Plain	0.20	0.10	84%	88%	66%	72%
234D	White and Black River Alluvial Plains	0.40	0.25	76%	74%	39%	49%
234E	Arkansas Alluvial Plains	0.31	0.16	78%	90%	70%	66%
251C	Central Dissected Till Plains	2.39	1.43	93%	95%	70%	63%
251D	Central Till Plains and Grand Prairies	0.33	0.23	87%	94%	71%	78%
251E	Osage Plains	0.35	0.06	92%	83%	42%	19%
M211B	New England Piedmont	1.48	0.19	89%	95%	71%	82%
M221A	Northern Ridge and Valley	7.20	3.68	89%	94%	64%	73%
M221B	Allegheny Mountains	2.95	1.32	93%	96%	62%	75%
M221C	Northern Cumberland Mountains	4.60	2.48	88%	95%	42%	68%
M221D	Blue Ridge Mountains	6.65	3.19	87%	94%	50%	73%
M223A	Boston Mountains	2.10	1.72	80%	90%	29%	53%
M231A	Ouachita Mountains	2.96	2.01	70%	78%	28%	49%
	Total	131.74	77.65	83%	83%	54%	52%

TASK 6: INVESTIGATE EFFECTS OF PLAUSIBLY INFLUENTIAL FACTORS

SITE PRODUCTIVITY

Upland oak seedling abundance showed a general decreasing pattern with increasing site productivity (Figure 43). All upland oak seedlings combined averaged about 500 seedlings per acre on plots with the poorest site quality and less than half that on sites with the highest productivity.

While the pattern of decreasing seedling abundance with increasing site productivcity was apparent when all upland oak species were combined, for individual species the relationship was not always strong or even apparent. For example, southern red oak exhibited a slight increase in seedling abundance with increasing site productivity. For white oak, this metric of site productivity appeared to have little influence on seedling abundance.

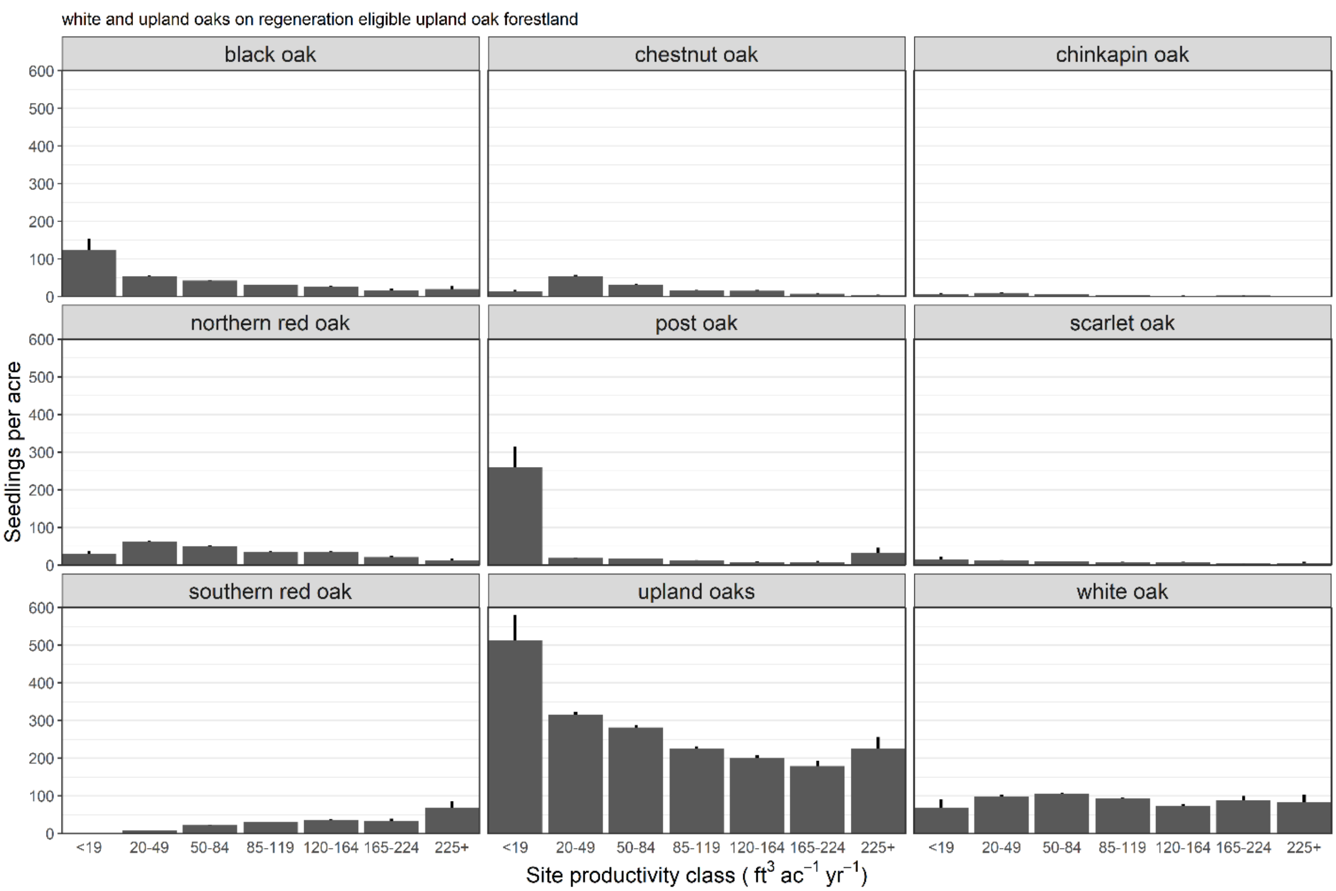


Figure 43. Upland oak seedling abundance by species and site productivity class, trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Upland oak panel combines all eight species. Errorbars depict sampling error (≈ 68% confidence or 1 standard deviation). Site productivity classes correspond approximately to white oak site index values of 35, 55, 65, 70, 80, 100, and 110 ft. at a 50 year base age.

Physiographic classes provide additional insight into the relationship between site and regeneration potential for upland oaks by attempting to capture the general effect of land form, topographical position, and soil on moisture available to trees. We found that drier sites generally had greater upland oak seedling abundance than those with greater moisture availability (Figure 44). This pattern was also evident for white oak and most other upland oak species, with some species showing a propensity for a particular physiographic class along with a xeric-mesic decreasing gradient. For example, black oak seedling abundance tended to be higher on more xeric sites, but particularly high on deep sands.

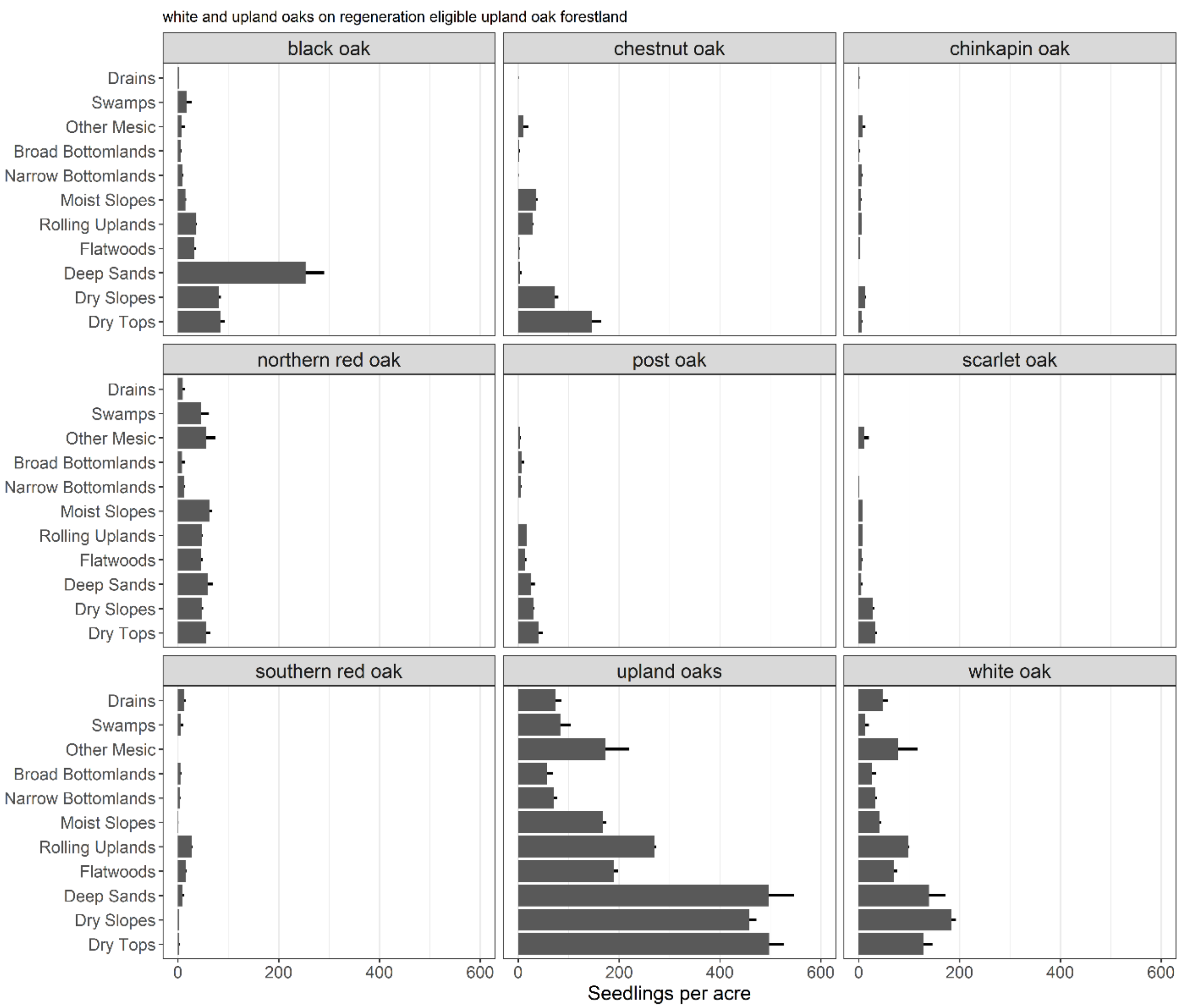


Figure 44. Upland oak seedling abundance by species and physiogrpahic class, trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Upland oak panel combines all eight upland oak species. Errorbars depict sampling error and represent (≈ 68% confidence or 1 standard deviation).

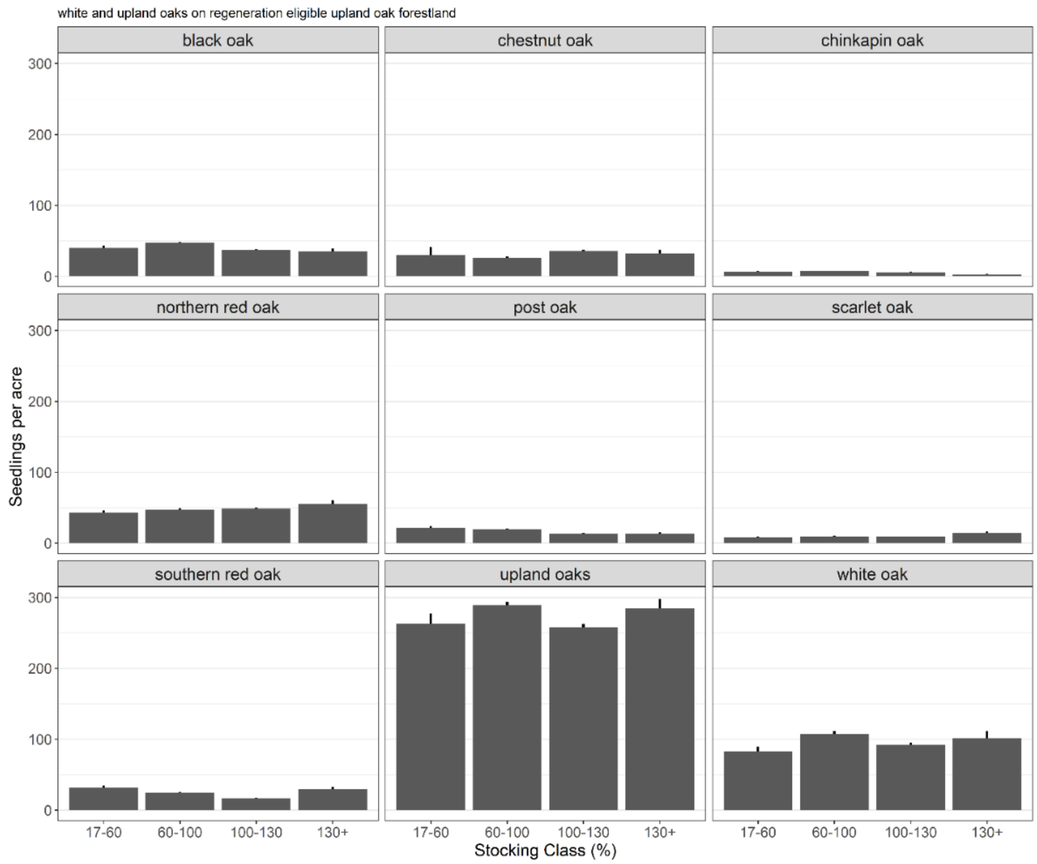


Figure 45. Upland oak seedling abundance by species and stocking class, trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Upland oak panel combines all eight upland oak species. Errorbars depict sampling error and represent (≈ 68% confidence or 1 standard deviation).

Surprisingly, there was not clear evidence that stocking/density influenced seedling abundance with the metric used in this analysis (Figure 45). However, forest composition did appear to influence upland oak seedling abundance and white oak individually. Among forest types with at least 20 regeneration eligible upland oak plots, white oak seedling abundance was greatest in the white oak forest type (504), but also notably higher in many forest types that had major pine components (Figure 46), especially shortleaf or Virginia pines (162,163,404,405). In fact, white oak seedling abundance was higher in those forest types than in all oak/hickory forest types except for the white oak type (Table 7).

For all upland oak species combined, the pattern of increased abundance under canopies with heavy conifer components such as shortleaf and Virginia pines was perhaps more robust as white, red, and jack pines along with eastern redcedar all showed relatively higher upland oak seedling abundance than most other forest types (Figure 47). Only the post oak-blackjack oak, chestnut oak, and white oak forest types within the oak/hickory forest type group exhibited comparable upland oak seedling abundances.

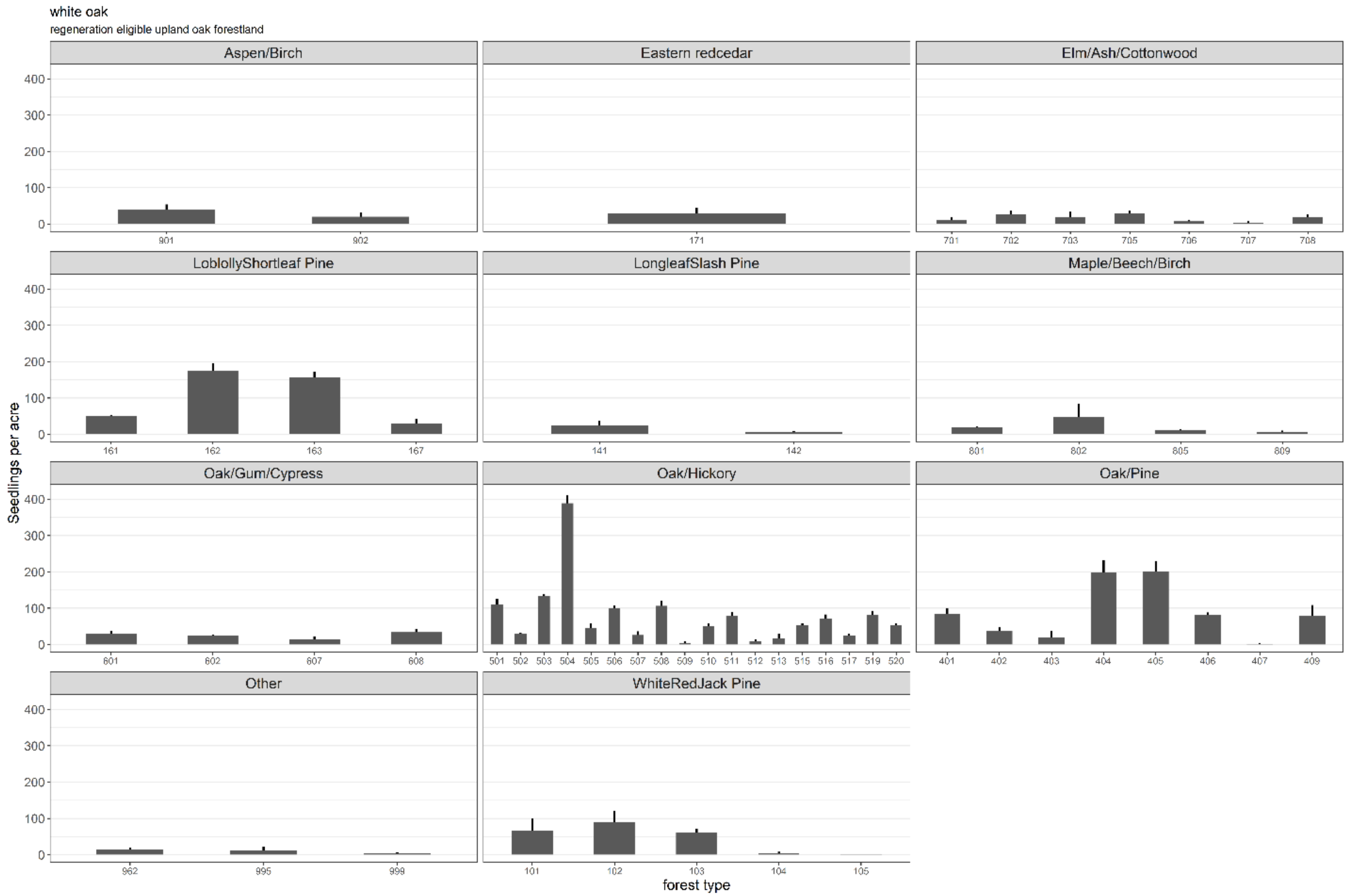


Figure 46. White oak seedling abundance by forest type, trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Panels depict forest types within the same forest type group, a higher level classification. Corresponding forest type names can be found in Table 7, e.g., type 504 = White oak. Errorbars depict sampling error and represent (≈ 68% confidence or 1 standard deviation).

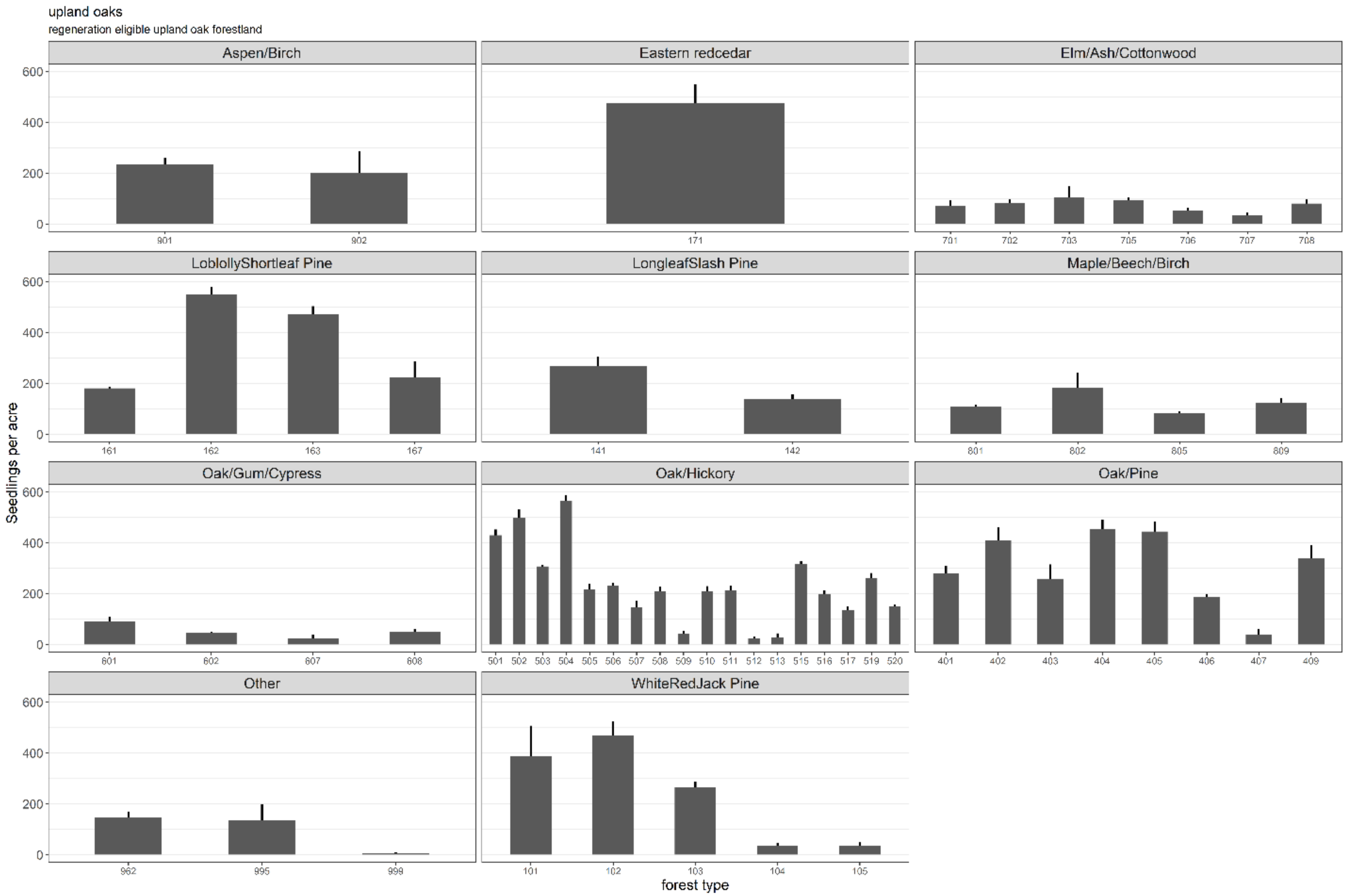


Figure 47. Upland oak seedling abundance by forest type, trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Panels depict forest types within the same forest type group, a higher level classification. Corresponding forest type names can be found in Table 7, e.g., type 504 = White oak. Errorbars depict sampling error and represent (≈ 68% confidence or 1 standard deviation).

Table 7. White and upland oak seedling abundance by forest type, trees per acre, eastern US regeneration eligible upland oak forestland, 2017. SE indicates sampling error (≈ 68% confidence or 1 standard deviation).

Forest type group	FORTYPCD	Forest type	Upland oaks		White oak	
			TPA	SE	TPA	SE
			... seedlings per acre ...			
White/Red/Jack Pine	101	Jack pine	322	116	65	34
White/Red/Jack Pine	102	Red pine	380	44	89	33
White/Red/Jack Pine	103	E. white pine	204	21	61	10
White/Red/Jack Pine	104	E. white pine-E. hemlock	31	10	5	3
White/Red/Jack Pine	105	E. hemlock	35	13	1	1
Longleaf/Slash Pine	141	Longleaf pine	246	33	23	15
Longleaf/Slash Pine	142	Slash pine	131	20	6	2
Loblolly/Shortleaf Pine	161	Loblolly pine	131	4	49	3
Loblolly/Shortleaf Pine	162	Shortleaf pine	375	22	176	20
Loblolly/Shortleaf Pine	163	Virginia pine	316	28	156	16
Loblolly/Shortleaf Pine	167	Pitch pine	192	62	30	13
Loblolly/Shortleaf Pine	168	Spruce pine	17	16	14	13
Other E. Softwoods	171	E. redcedar	446	73	29	17
Exotic softwoods	381	Scotch pine	349	133	26	20
Oak-Pine	401	E. white pine-N. red oak- white ash	194	26	85	15
Oak-Pine	402	E. redcedar-hardwood	372	51	36	11
Oak-Pine	403	Longleaf pine-oak	240	53	19	17
Oak-Pine	404	Shortleaf pine-oak	254	18	198	34
Oak-Pine	405	Virginia pine-S. red oak	243	28	201	27
Oak-Pine	406	Loblolly pine-hardwood	106	7	80	7
Oak-Pine	407	Slash pine-hardwood	37	23	2	2
Oak-Pine	409	Other pine-hardwood	258	45	80	29
Oak-Hickory	501	Post/blackjack oak	319	16	111	16
Oak-Hickory	502	Chestnut oak	469	34	29	4
Oak-Hickory	503	White/red oak-hickory	174	4	134	4
Oak-Hickory	504	White oak	175	7	389	23
Oak-Hickory	505	N. red oak	172	15	45	13
Oak-Hickory	506	Tuliptree-white/N. red oak	132	8	99	7
Oak-Hickory	507	Sassafras-persimmon	121	22	26	11
Oak-Hickory	508	Sweetgum-tuliptree	105	8	106	15
Oak-Hickory	509	Bur oak	39	11	4	4
Oak-Hickory	510	Scarlet oak	159	19	50	9
Oak-Hickory	511	Tuliptree	133	14	79	11
Oak-Hickory	512	Black walnut	15	6	8	5

Forest type group	FORTYPCD	Forest type	Upland oaks		White oak	
			TPA	SE	TPA	SE
Oak-Hickory	513	Black locust	13	7	16	14
Oak-Hickory	515	Chestnut/black/scarlet oak	262	13	53	5
Oak-Hickory	516	Cherry-white ash-tuliptree	127	10	71	11
Oak-Hickory	517	Elm-ash-black locust	112	15	23	5
Oak-Hickory	519	Red maple-oak	180	16	81	12
Oak-Hickory	520	Mixed upland hardwoods	98	5	53	5
Oak-Gum-Cypress	601	Swamp chestnut/cherrybark oak	62	13	30	9
Oak-Gum-Cypress	602	Sweetgum-Nuttall/willow oak	21	4	24	4
Oak-Gum-Cypress	607	Baldcypress-water tupelo	10	10	15	8
Oak-Gum-Cypress	608	Sweetbay-swamp tupelo-red maple	15	5	34	10
Elm-Ash-Cottonwood	701	Black ash-A. elm-red maple	59	22	12	6
Elm-Ash-Cottonwood	702	River birch-sycamore	54	10	28	9
Elm-Ash-Cottonwood	703	Cottonwood	85	41	18	17
Elm-Ash-Cottonwood	705	Sycamore-pecan-A. elm	64	10	30	8
Elm-Ash-Cottonwood	706	Sugar/hackberry-elm-green ash	47	11	7	3
Elm-Ash-Cottonwood	707	Silver maple-A. elm	30	10	4	4
Elm-Ash-Cottonwood	708	Red maple-lowland	62	14	19	8
Maple/Beech/Birch	801	Sugar maple-beech-yellow birch	88	8	19	3
Maple/Beech/Birch	802	Black cherry	133	48	48	36
Maple/Beech/Birch	805	Hard maple-basswood	72	8	11	3
Maple/Beech/Birch	809	Red maple-upland	117	18	7	3
Aspen/Birch	901	Aspen	192	25	41	13
Aspen/Birch	902	Paper birch	180	86	20	11
Other hardwoods	962	Other hardwoods	133	23	14	5
Exotic Hardwoods	995	Other exotic hardwoods	124	61	11	11
Nonstocked	999	Nonstocked	2	2	4	3

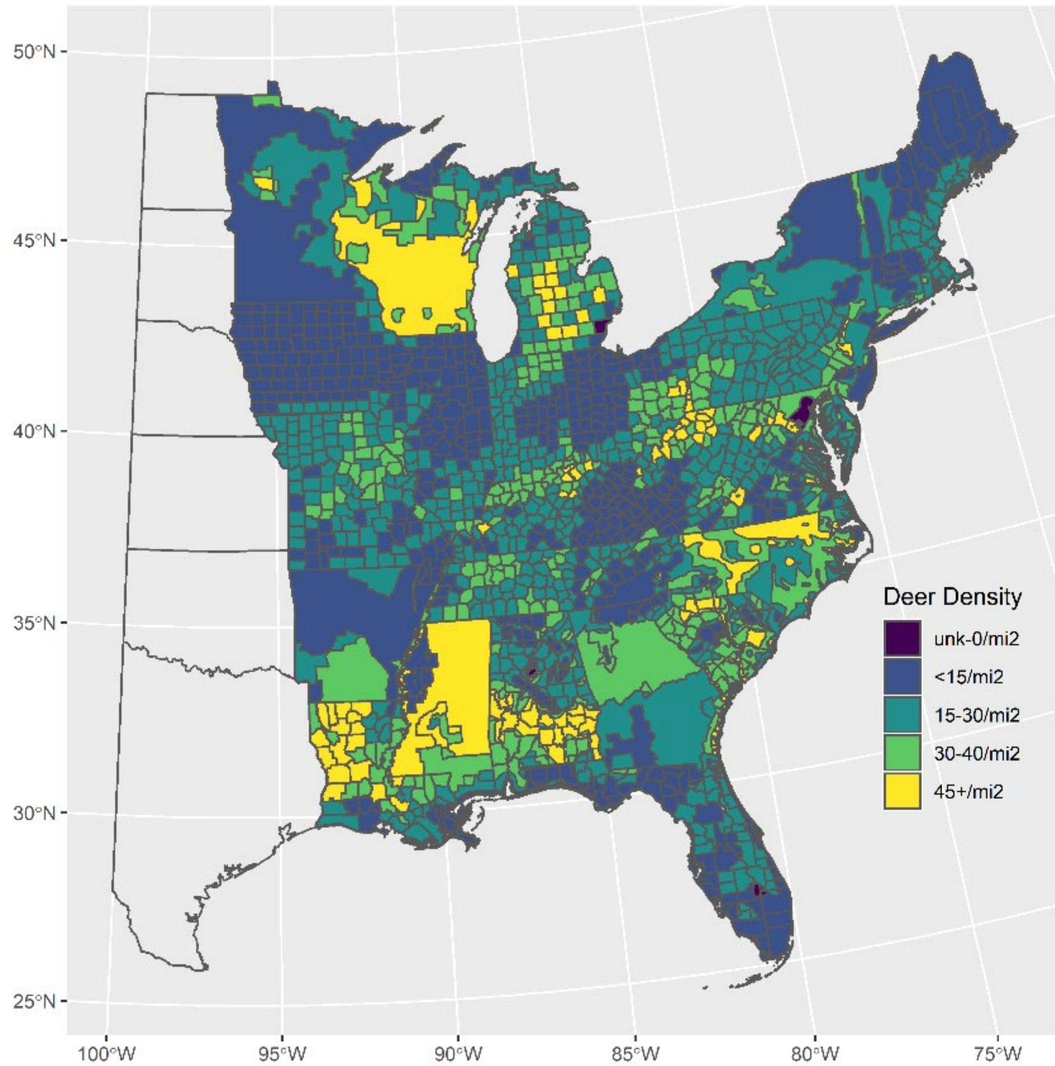


Figure 48. Deer density class estimates for the eastern US[1].

Deer densities varied across the upland oak range and in some cases across relatively small areas. Generally, estimates of deer density was highest in Wisconsin, parts of the mid-Atlantic region and parts of Louisiana, Mississippi, and Alabama (Figure 48). For all upland oaks combined, increasing deer density was associated with decreasing seedling abundance (Figure 49). There was some evidence that increasing deer density was associated with either lower or no change in seedling abundance across all upland oak species except southern red oak. Southern red oak showed slight increases in seedling abundance with increasing deer density. There was a noticeable influence of deer browsing on white oak seedling abundance, though perhaps not as strong between lower classes as all upland oaks combined.

[1] Estimates from Walters et al. (2016)

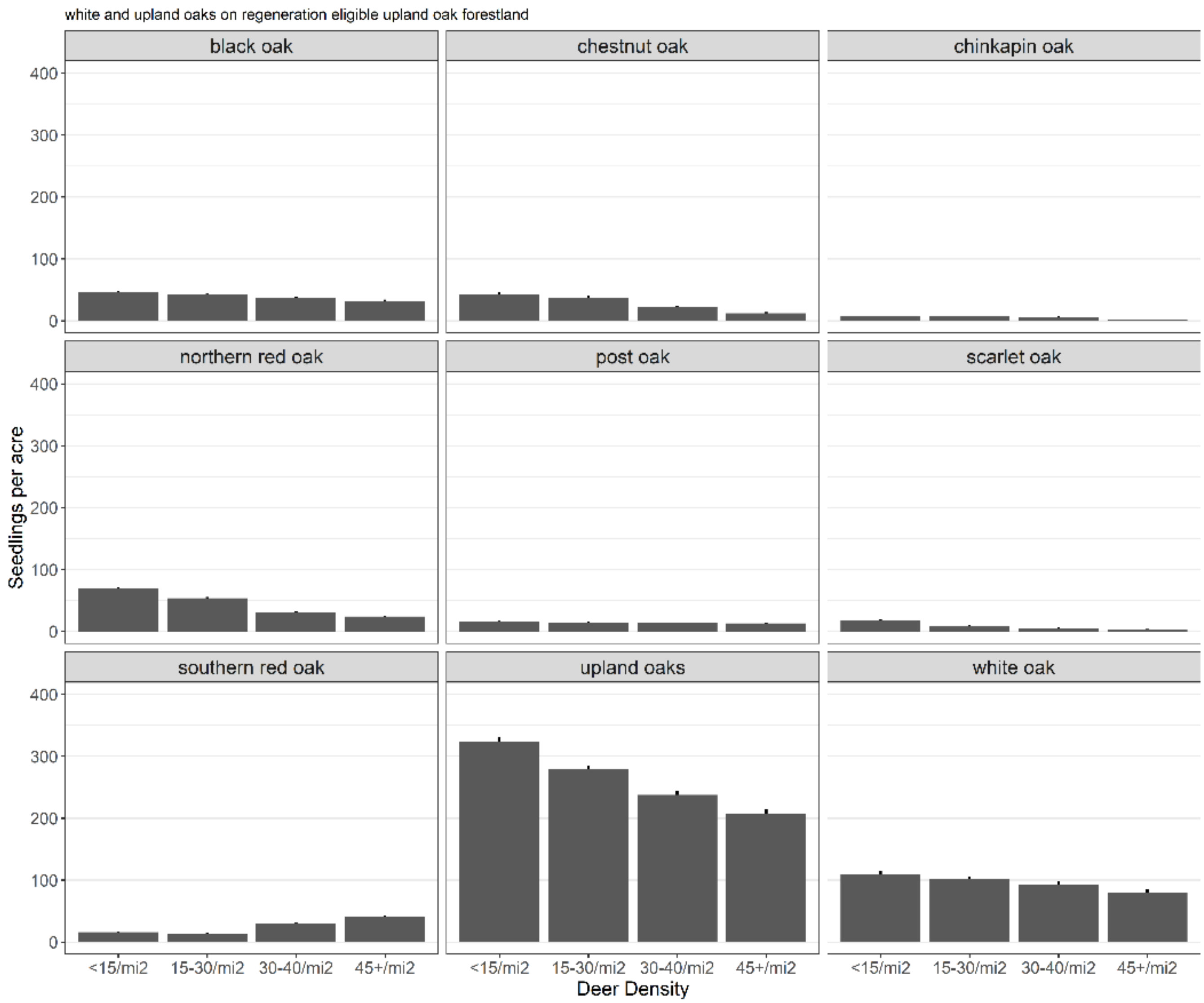


Figure 49. Upland oak seedling abundance by species and deer density class, trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Upland oak panel combines all eight upland oak species. Errorbars depict sampling error (≈ 68% confidence or 1 standard deviation).

LAND OWNERSHIP

Generally, upland oak seedlings are more abundant on US Forest Service forestland while private forestland had the least abundant seedlings. While this pattern was evident for upland oaks combined, the ownership influence did not appear to be uniform or equally strong across all species individually (Figure 50).

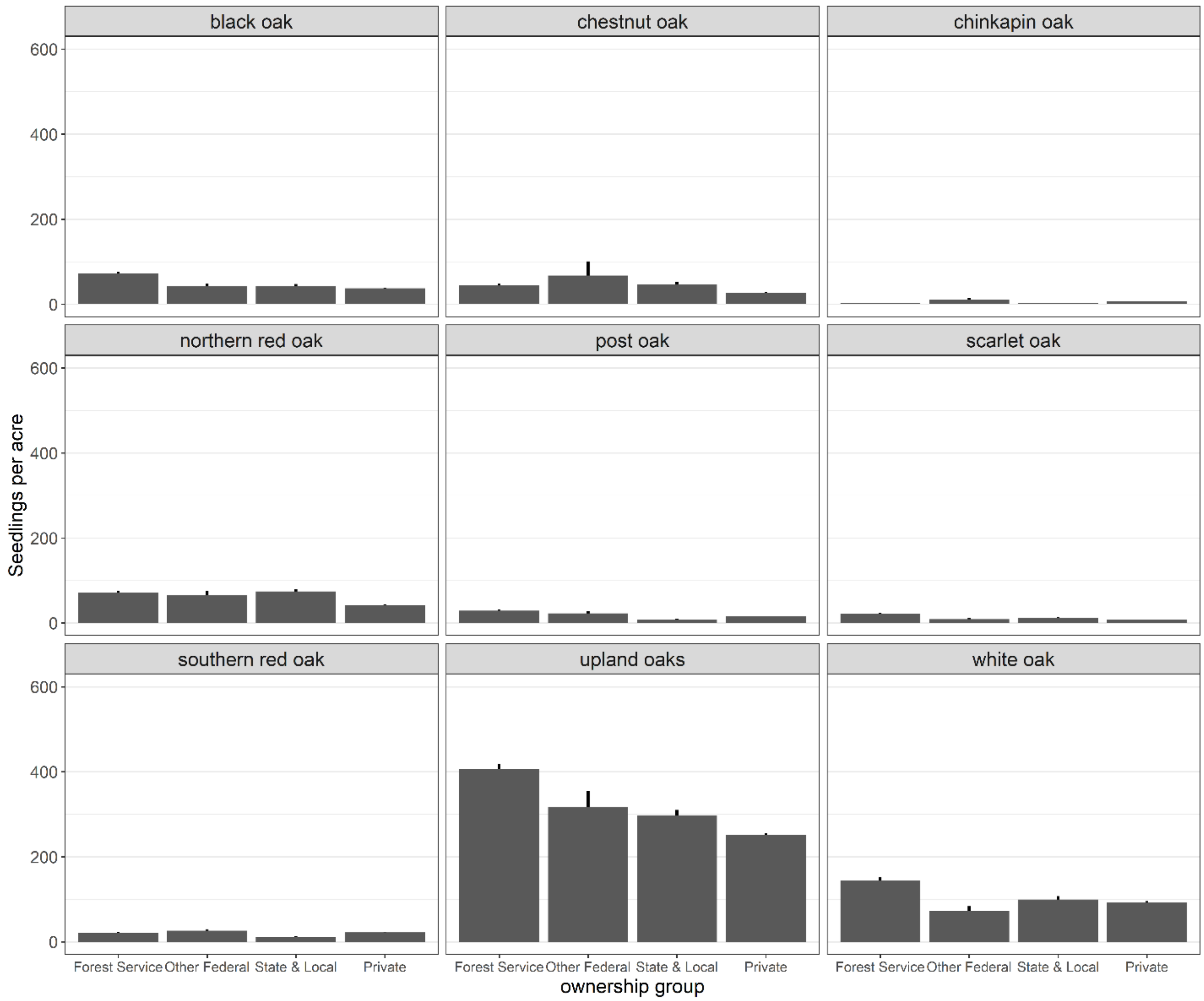


Figure 50. Upland oak seedling abundance by species and land ownership class, trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Upland oak panel combines all eight upland oak species. Errorbars depict sampling error (≈ 68% confidence or 1 standard deviation).

OTHER DISTURBANCES

The occurrence and type of disturbance appears to influence average upland oak seedling abundance. On average, plots with disease-based disturbances clearly have fewer upland oak seedlings than those with no disturbance, while insect-based disturbances have perhaps slightly less abundant seedlings than undisturbed plots (Figure 51). On the other hand, fire- and weather-based disturbances appear to have higher average oak seedling abundances than undisturbed plots. There is also some evidence that the influence of a particular type of disturbance may differ among upland oak species. For example, fire-based disturbances appear to favor post oak and southern red oak seedling abundance while other species showed little to apparent negative responses.

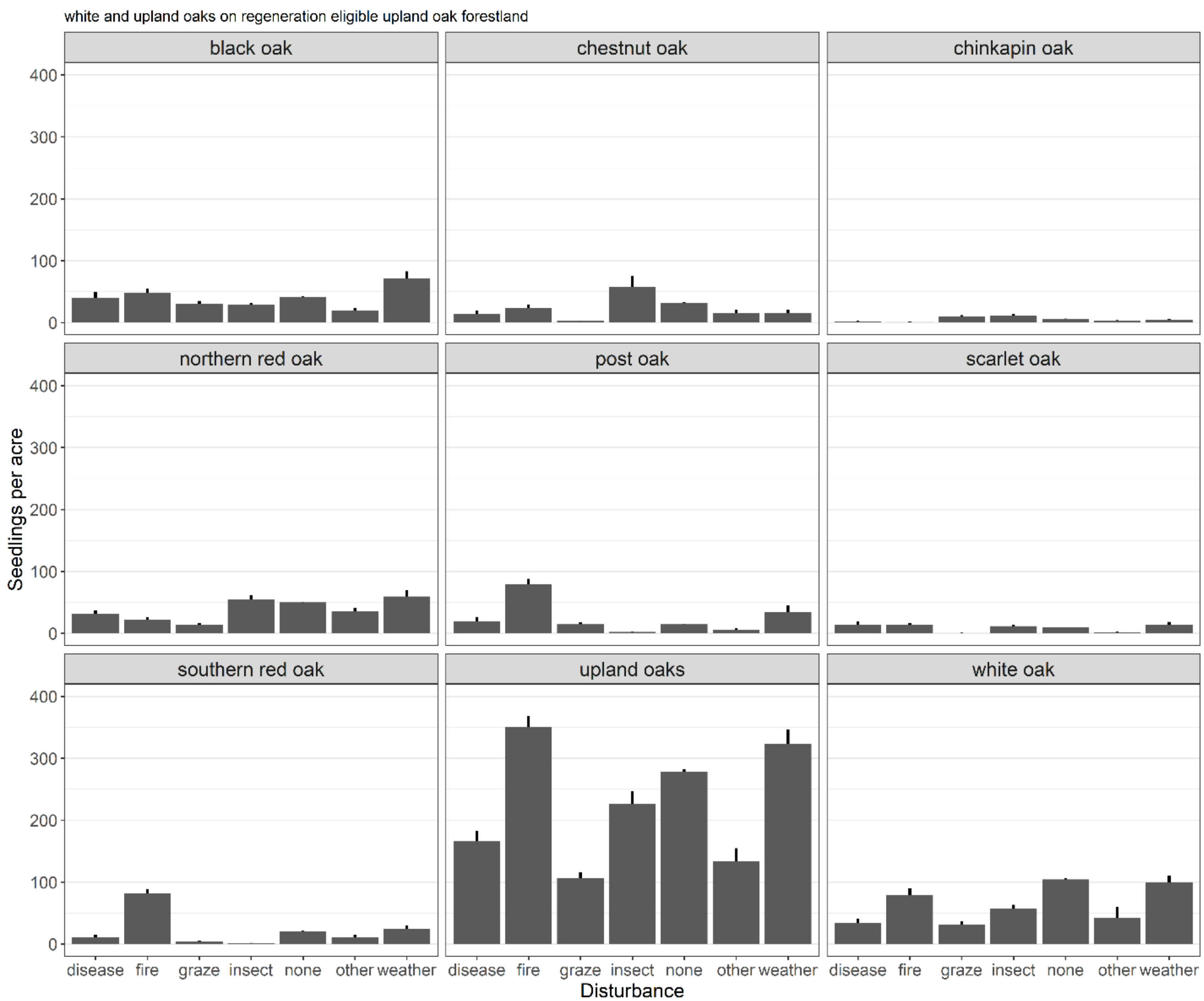


Figure 51. Upland oak seedling abundance by species and disturbance type, trees per acre (dbh < 1 in.; height ≥ 12 in.), eastern US regeneration eligible upland oak forestland, 2017. Upland oak panel combines all eight upland oak species. Errorbars depict sampling error (≈ 68% confidence or 1 standard deviation).

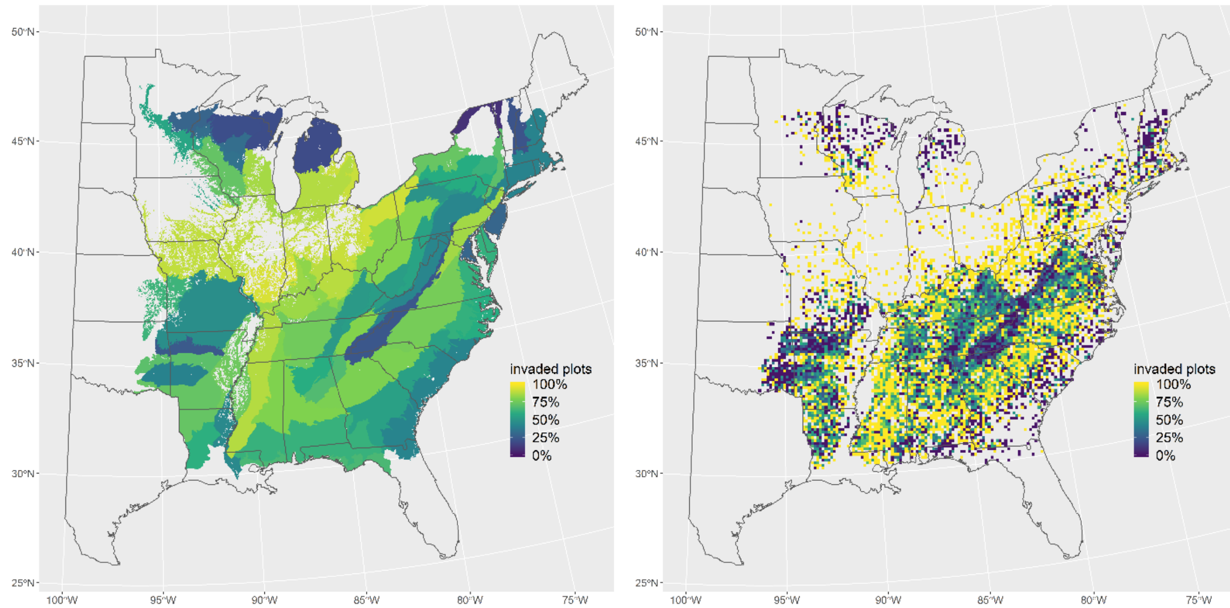


Figure 52. Invasive plant species presence by ecological section and local scale, % plots where invasive plant species were inventoried and observed, ecological section [L] and local scale [R], eastern US regeneration eligible upland oak forestland, 2017. Each local scale cell represents ≈ 48,000 acres.

The proportion of invaded plots within an ecological section ranged from 9% (211E) to 94% (223G), and averaged ≈ 60% across regeneration eligible upland oak forestland in ecological sections (Figure 52). Among the largest ecological sections (≥ 1 million regeneration eligible upland oak acres), the Central Dissected Till Plains (251C), Interior Low Plateau-Bluegrass (223F), Coastal Plains-Loess (231H), South Central Great Lakes (222J), and Northern Appalachian Piedmont (221D) sections all have invasive plants recorded on ≥ 85% of inventoried plots. In contrast, the Northern Lower Peninsula (212H), New England Piedmont (M211B), Blue Ridge Mountains (M221D), and Boston Mountains (M223A) were the only ecological sections with < 25% of plots invaded. All others sections ranged from ≈ 40-80% invaded.

There were 64 unique invasive plant species recorded across regeneration eligible upland oak forestland, and some species are more prominent than others. The 3 most frequently occurring invasive plant species within each ecological section includes only 25 unique species, while the top 3 invasives for each section by cover includes 27 unique species (Table 8). For both frequency and cover, Japanese honeysuckle, Nepalese browntop and multiflora rose were the three most prominent species across all ecological sections, with Japanese honeysuckle clearly being the most prominent invasive species for both frequency of occurrence and cover (Figure 53).

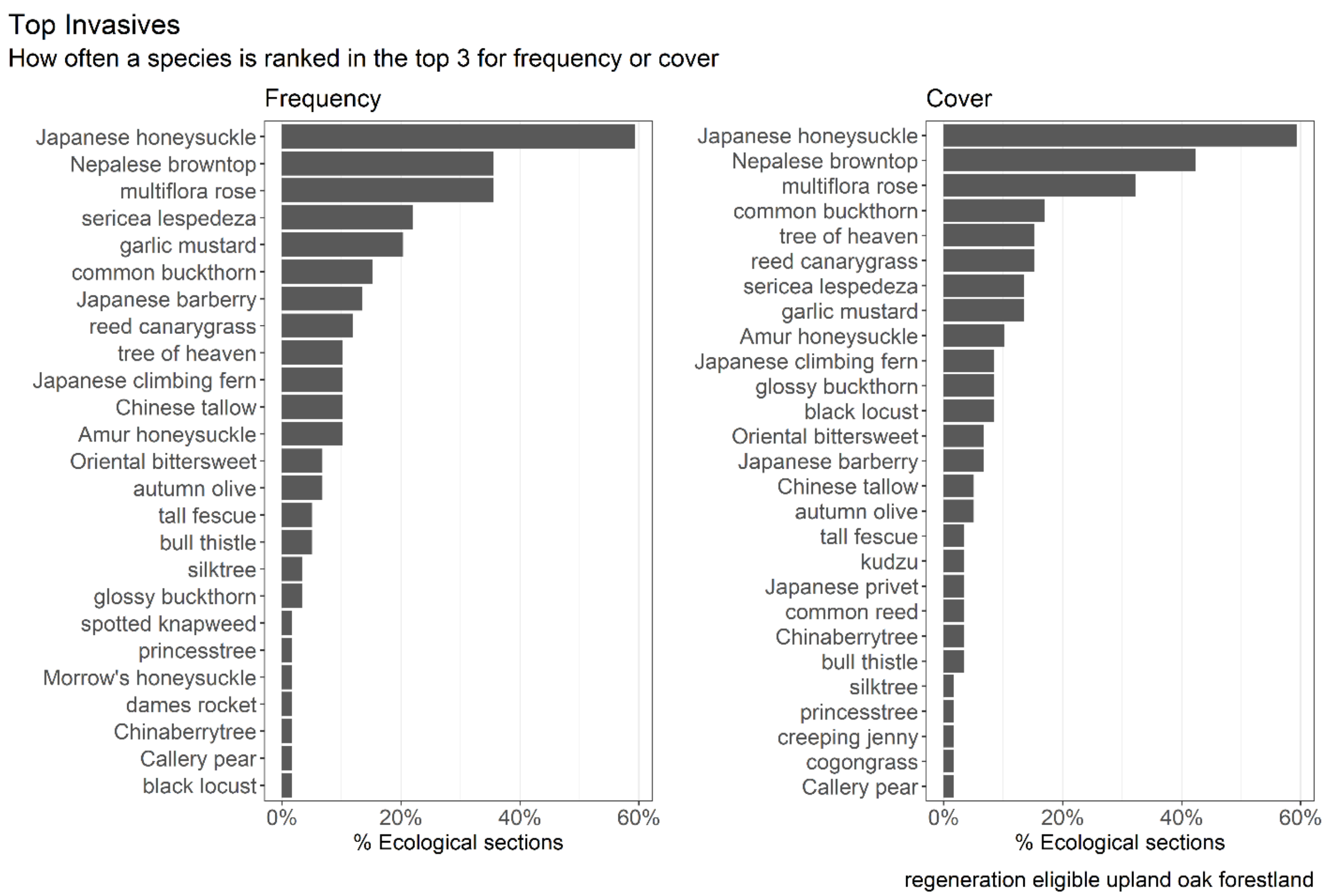


Figure 53. Prominent invasive plant species across all ecological sections by attribute, includes species most commonly ranked in the top three for frequency [L] or cover [R] at the ecological section scale, eastern US regeneration eligible upland oak forestland, 2017. Common names provided follow USDA NRCS PLANTS Database[1].

[1] https://plants.sc.egov.usda.gov/java/

Table 8. Prominent invasive plant species across by attribute and ecological section, includes species ranked in the top three for frequency [L] or cover [R] for each section, eastern US regeneration eligible upland oak forestland, 2017. Common names provided follow USDA NRCS PLANTS Database[1].

SCT_CD	Top three invasive plants by attribute and ecological section					
	Frequency			Cover		
211E	Japanese barberry			Japanese barberry		
211F	multiflora rose	autumn olive	Morrow's honeysuckle	multiflora rose	autumn olive	Nepalese browntop
211G	multiflora rose	Japanese barberry	Nepalese browntop	multiflora rose	Nepalese browntop	Japanese barberry
211I	garlic mustard	Japanese barberry	dames rocket	garlic mustard	common buckthorn	multiflora rose
212H	spotted knapweed	reed canarygrass	autumn olive	reed canarygrass	black locust	glossy buckthorn
212K	reed canarygrass	common buckthorn	bull thistle	glossy buckthorn	reed canarygrass	common buckthorn
212Q	common buckthorn	reed canarygrass	bull thistle	common buckthorn	reed canarygrass	bull thistle
212T	bull thistle	autumn olive	reed canarygrass	bull thistle	reed canarygrass	autumn olive
212X	common buckthorn	reed canarygrass	Amur honeysuckle	common buckthorn	reed canarygrass	Amur honeysuckle
221A	Japanese barberry	Oriental bittersweet	multiflora rose	Japanese barberry	glossy buckthorn	Oriental bittersweet
221B	multiflora rose	Japanese barberry	Oriental bittersweet	Japanese barberry	Oriental bittersweet	multiflora rose
221D	Japanese honeysuckle	Nepalese browntop	Oriental bittersweet	Nepalese browntop	Japanese honeysuckle	Oriental bittersweet
221E	multiflora rose	Japanese honeysuckle	Nepalese browntop	multiflora rose	Nepalese browntop	Japanese honeysuckle
221F	multiflora rose	garlic mustard	Japanese barberry	multiflora rose	garlic mustard	Nepalese browntop
221H	Japanese honeysuckle	Nepalese browntop	tree of heaven	Japanese honeysuckle	Nepalese browntop	tree of heaven
221J	Japanese honeysuckle	Nepalese browntop	tree of heaven	Japanese honeysuckle	Nepalese browntop	tree of heaven
222H	multiflora rose	garlic mustard	Amur honeysuckle	Amur honeysuckle	multiflora rose	garlic mustard
222I	multiflora rose	common buckthorn	garlic mustard	common buckthorn	multiflora rose	creeping jenny
222J	multiflora rose	autumn olive	garlic mustard	autumn olive	multiflora rose	black locust
222K	common buckthorn	garlic mustard	multiflora rose	common buckthorn	garlic mustard	reed canarygrass
222L	common buckthorn	multiflora rose	garlic mustard	common buckthorn	garlic mustard	multiflora rose
222M	common buckthorn	reed canarygrass	Amur honeysuckle	common buckthorn	reed canarygrass	Amur honeysuckle
222R	reed canarygrass	common buckthorn	glossy buckthorn	glossy buckthorn	common buckthorn	reed canarygrass
222U	multiflora rose	Japanese barberry	common buckthorn	common reed	common buckthorn	multiflora rose
223A	multiflora rose	Japanese honeysuckle	sericea lespedeza	Japanese honeysuckle	multiflora rose	sericea lespedeza
223B	Japanese honeysuckle	Nepalese browntop	multiflora rose	Nepalese browntop	Japanese honeysuckle	multiflora rose
223D	Japanese honeysuckle	Nepalese browntop	multiflora rose	Japanese honeysuckle	Nepalese browntop	multiflora rose
223E	Japanese honeysuckle	Nepalese browntop	tree of heaven	Japanese honeysuckle	Nepalese browntop	tree of heaven
223F	Japanese honeysuckle	garlic mustard	Nepalese browntop	Japanese honeysuckle	Nepalese browntop	garlic mustard
223G	multiflora rose	Japanese honeysuckle	Amur honeysuckle	Japanese honeysuckle	Amur honeysuckle	multiflora rose

[1] https://plants.sc.egov.usda.gov/java/

SCT_CD	Top three invasive plants by attribute and ecological section					
	Frequency			Cover		
231A	Japanese honeysuckle	sericea lespedeza	Nepalese browntop	Japanese honeysuckle	Nepalese browntop	sericea lespedeza
231B	Japanese honeysuckle	sericea lespedeza	Japanese climbing fern	Japanese honeysuckle	Nepalese browntop	sericea lespedeza
231C	Japanese honeysuckle	Nepalese browntop	silktree	Japanese honeysuckle	Nepalese browntop	sericea lespedeza
231D	Japanese honeysuckle	Nepalese browntop	silktree	Japanese honeysuckle	Nepalese browntop	Japanese privet
231E	Japanese honeysuckle	Chinese tallow	sericea lespedeza	Japanese honeysuckle	silktree	Chinese tallow
231G	Japanese honeysuckle	sericea lespedeza	tall fescue	Japanese honeysuckle	sericea lespedeza	tall fescue
231H	Japanese honeysuckle	Japanese climbing fern	Nepalese browntop	Japanese honeysuckle	Nepalese browntop	Japanese climbing fern
231I	Japanese honeysuckle	Nepalese browntop	tree of heaven	Japanese honeysuckle	Nepalese browntop	tree of heaven
232A	Japanese honeysuckle	multiflora rose	Nepalese browntop	Japanese honeysuckle	common reed	black locust
232B	Japanese honeysuckle	Japanese climbing fern	Chinese tallow	Japanese honeysuckle	Japanese climbing fern	cogongrass
232C	Japanese honeysuckle	Chinese tallow	sericea lespedeza	Japanese honeysuckle	Chinaberrytree	Japanese privet
232F	Japanese honeysuckle	Japanese climbing fern	Chinese tallow	Japanese honeysuckle	Japanese climbing fern	Chinese tallow
232H	Japanese honeysuckle	Nepalese browntop	sericea lespedeza	Japanese honeysuckle	Nepalese browntop	tree of heaven
232I	Japanese honeysuckle	Nepalese browntop	sericea lespedeza	Japanese honeysuckle	Nepalese browntop	princesstree
232J	Japanese honeysuckle	sericea lespedeza	Chinaberrytree	Japanese honeysuckle	kudzu	Chinaberrytree
232L	Japanese climbing fern	Chinese tallow	Japanese honeysuckle	Japanese climbing fern	Chinese tallow	Japanese honeysuckle
234A	Japanese honeysuckle	Japanese climbing fern	Chinese tallow	Japanese honeysuckle	Japanese climbing fern	Nepalese browntop
234D	Japanese honeysuckle	sericea lespedeza	princesstree	Japanese honeysuckle	Nepalese browntop	kudzu
234E	Japanese honeysuckle	Callery pear	sericea lespedeza	Japanese honeysuckle	Callery pear	sericea lespedeza
251C	multiflora rose	Amur honeysuckle	garlic mustard	multiflora rose	Amur honeysuckle	black locust
251D	multiflora rose	Amur honeysuckle	garlic mustard	Amur honeysuckle	multiflora rose	garlic mustard
251E	multiflora rose	Japanese honeysuckle	garlic mustard	multiflora rose	Japanese honeysuckle	garlic mustard
M211B	Oriental bittersweet	glossy buckthorn	Japanese barberry	reed canarygrass	glossy buckthorn	Oriental bittersweet
M221A	Nepalese browntop	Japanese honeysuckle	garlic mustard	Nepalese browntop	Japanese honeysuckle	tree of heaven
M221B	multiflora rose	black locust	Nepalese browntop	Nepalese browntop	black locust	multiflora rose
M221C	Nepalese browntop	Japanese honeysuckle	tree of heaven	Nepalese browntop	Japanese honeysuckle	tree of heaven
M221D	Nepalese browntop	Japanese honeysuckle	tree of heaven	Nepalese browntop	Japanese honeysuckle	tree of heaven
M223A	Japanese honeysuckle	sericea lespedeza	tall fescue	Japanese honeysuckle	sericea lespedeza	tree of heaven
M231A	Japanese honeysuckle	sericea lespedeza	tall fescue	Japanese honeysuckle	sericea lespedeza	tall fescue

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