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CURRENT STATUS OF CHESTNUT IN EASTERN US FORESTS

William H. McWilliams[1], Tonya W. Lister[1], Elizabeth B. LaPoint[1], Anita K. Rose[2], and John S. Vissage[3]
[1] USDA Forest Service, Northeastern Research Station, Newtown Square, PA 19081 USA
(wmcwilliams@fs.fed.us)
[2] USDA Forest Service, Southern Research Station, Knoxville, TN USA 37919
[3] USDA Forest Service, North Central Research Station, St. Paul, MN USA 55108

Abstract: The USDA Forest Service, Forest Inventory and Analysis (FIA) program provides the opportunity to assess the current distribution of American chestnut (*Castanea dentata* (Marsh.) Borkh) and prospective trends. Assessing chestnut using the FIA data was challenging because of the coarse nature of the FIA sample and chestnut's rarity in natural forests; however, a basic analysis of location and character provide important information for scientists seeking to re-establish chestnut. Chestnut occurred from Vermont to Alabama or from roughly 45° to 30° north latitude. The estimate of the area of forest land with chestnut at least 1.0-inch in diameter was 2.8 million acres. The area with the highest concentration of chestnut aligned well with Braun's oak-chestnut forest region. About two-thirds of the chestnut sample was on private land and 87 percent was found in oak-hickory stands that vary considerably in composition from north to south. Derivation of a population estimate for the total number of chestnut stems was precluded by missing data. Trends in the existing sample of sapling and tree-size stems suggest a decrease in sapling-size stems and an increase in tree-size stems. Future research on chestnut using FIA data could include filling in data gaps as new inventories are completed, development of improved indicators using new national core health variables, and analysis using geographic information systems (GIS).

Keywords: American chestnut / *Castanea dentata* / distribution / map / Forest Inventory and Analysis / oak-chestnut forest region.

INTRODUCTION

American chestnut (*Castanea dentata* (Marsh.) Borkh.) is still a component of the forest understory in much of its native range despite its extirpation as an overstory component by the chestnut blight (*Endothia parasitica* (Murr.) Anders and Anders) (*Cryphonectria parasitica* (Murrill) Barr.) beginning in the early 1900's (Paillet 1988, Stephenson and Adams 1991). The USDA Forest Service, Forest Inventory and Analysis (FIA) program conducts large-scale forest inventories across the United States and provides the opportunity to assess the current distribution of chestnut and prospective trends. Assessing chestnut using the FIA data was challenging because of the coarse nature of the FIA sample and chestnut's rarity in natural forests. However some basic analyses of location and character can provide important information for scientists seeking to re-establish chestnut. An examination and analysis of available data is provided, along with cautionary comments on data interpretation.

MATERIALS AND METHODS

In 1999, the FIA program converted from a periodic system, in which states were inventoried every 10 to 15 years, to an annual system with fixed portions of a state's forests measured annually. FIA uses a three-phase system to inventory and monitor forests. Phase 1 uses remote sensing to stratify the land base as forest and nonforest and assign a representative number of acres to each sample plot measured in Phase 2.

Phase 2 consists of field measurements collected on a grid of sample plots spread across the United States. Each plot is made up of four 24-foot circular fixed-radius subplots for inventory of trees at least 5.0 inches in diameter. Trees less than 5.0 inches are inventoried on 6.8-foot circular fixed-radius micro-plots nested within each subplot. At each sample plot, a suite of plot and tree-level measurements are collected. Each Phase 2 plot represents about 6,000 acres, although some states have intensified sample grids. Phase 3 measurements are collected on a limited number of Phase 2 locations and include more detailed forest-health parameters, such as tree crown condition.

The Phase 2 sample data were used to identify locations where chestnut occurs and to characterize sites, stands, and tree sizes. Tree-size class provides a surrogate for age or stage of development. Seedlings are trees that are less than 1.0-inch in diameter and at least 0.5 and 1.0 feet in height for coniferous and deciduous species, respectively. Saplings range from 1.0 to 4.9 inches. Tree size is defined as 5.0 inches in diameter and larger. The population estimate of the total forest land acreage with chestnut is mentioned; however, it should be recognized that chestnut's occurrence is rare and discontinuous, so the accuracy and precision of population estimates and related findings are often low.

Other sampling issues associated with chestnut may affect estimates and conclusions. Misidentification can occur because of confusion with Asian chestnuts, cultivars, and similar species. Allegheny chinkapin (*Castanea pumila* (Mill.)) shares much of the current distribution and may have resulted in errors of inclusion. Also, when tallying clumps of seedlings of a single species, FIA crews usually record the most dominant stem. In some older inventories, chestnut may have been grouped into a nonspecific species code. In other cases, seedling tallies were limited to the four most dominant species and only collected if no larger trees occurred on the sample plot. The lack of seedling data for all states was the major limitation of the study. Other less significant factors include differing sample grids, plot designs, and methods of measuring snags among states and inventory dates.

Data were screened for obvious outliers. Less obvious or questionable plots were allowed to remain in the dataset, recognizing that the distribution maps based on these data may contain errors of inclusion or exclusion. Errors of exclusion are often known. For example, FIA field staff in Pennsylvania reported many sightings of chestnut in the vicinity of sample plots, but chestnut was not actually sampled.

Despite these difficulties, FIA data are the only source of consistently gathered sample data on the contemporary occurrence of chestnut throughout its original distribution. Maps of chestnut distribution and related stand characteristics provide useful information for scientists interested in location and extent. More specific local results are available through herbarium studies and other monitoring.

Sources of FIA data used to characterize chestnut came from all available digital data for the states within the natural range of chestnut prior to the blight (Little 1977). This included data from the older periodic inventories and the new annual inventories for states where chestnut appeared in the inventory (Table 1). The most current inventories occurred from 1991 to 2002 and previous inventories from 1980 to 1995. In some cases, only one inventory was available. In order to minimize the amount of error introduced, annual inventory data were used only if at least 50 percent of the sample plots in any given state had been measured. Although this allowed the most current data to be used, some imprecision was apparent in the results. Other source data are contained in the numerous state-level reports published by FIA since the 1930s, but documenting the significant post-blight decline of the early and mid-1900s went beyond the objectives of this study. As such, the analysis covered the current resource and the latest trend information available.

Table 1. Sources of FIA data used to characterize contemporary occurrence and distribution of American chestnut in the eastern United States.

	Previous Inventory				Current Inventory			
State	Year	Inventory type	Number of forested plots	Number of plots with live chestnut[1]	Year	Inventory type	Number of forested plots	Number of plots with live chestnut[1]
Alabama	1990	Periodic	3923	3	2000	Periodic	4421	3
Connecticut	1985	Periodic	215	2	1998	Periodic	319	2
Georgia	1989	Periodic	7713	2	1997	Periodic	7272	4
Illinois	1985	Periodic	1169	0	1998	Periodic	1750	2
Indiana	1998	Periodic	1605	1	1999-2002	Annual	738	0
Kentucky	1988	Periodic	2005	4				
Maine	1995	Periodic	2733	1	1999-2002	Annual	2560	0
Maryland	1986	Periodic	716	3	1999	Annual	562	8
Massachusetts	1985	Periodic	243	1	1998	Periodic	583	14
Michigan	1993	Periodic	10849	0	2000-2002	Annual	4200	1
New Hampshire	1983	Periodic	590	4	1997	Periodic	853	4
New Jersey	1987	Periodic	254	2	1999	Periodic	429	4
New York	1993	Periodic	3063	14				
North Carolina	1984	Periodic	5676	37	1990	Periodic	5965	31
Ohio	1993	Periodic	1802	1				
Pennsylvania	1989	Periodic	3208	53	2000-2002	Annual	1929	19
Rhode Island	1985	Periodic	61	0	1998	Periodic	123	6
South Carolina	1993	Periodic	4563	1	1999-2001	Annual	2815	0
Tennessee	1989	Periodic	2315	4	1999	Periodic	2838	9
Virginia	1992	Periodic	4424	45	1998-2001	Annual	3169	41
West Virginia	1989	Periodic	2628	11	2000	Periodic	2188	21

[1] At least 1.0-inches in diameter.

RESULTS

Current Distribution

Chestnut samples plots were found between about 45° and 30° north latitude, but 85 percent were between 41° and 35° north latitude. Figure 1 depicts sample plots where live or dead chestnut trees at least 1.0 inch diameter were present in any of the inventories since 1980. Plots containing only dead trees were included to provide the most inclusive range description possible. Chestnut occurred from Vermont to Alabama and from Illinois in the west to Maine in the east. It was native to Ontario also, but FIA data do not cover Canada.

The estimate of forest land area with live chestnut at least 1.0 inch in diameter is 2.8 million acres. This estimate is based on the most recent cycle of inventories. The FIA definition of forest land includes areas at least 1 acre in size, at least 10 percent stocked with trees (or has been in the past), in a strip at least 120-feet wide, and not characterized by land uses that inhibit normal forest regeneration and succession (such as mowing). As such, some land with chestnut trees in fencerows or other land with trees would be excluded. It should also be noted that the estimate of forest land with chestnut would be higher if seedlings were included in the analysis.

Figure 1. Distribution of FIA sample plots where live or dead American chestnut trees were found through inventories conducted since 1980. Shaded area represents the Oak-Chestnut Forest Region (Braun 1950).

The top six states by number of sample plots with live trees at least 1.0-inch are Pennsylvania (53), Virginia (45), North Carolina (37), West Virginia (21), Massachusetts (14), and New York (14). Note that this ranking is based on a sample slightly different than the one depicted in Figure 1; this ranking is based on the most recent full periodic inventory of each state to utilize the largest sample possible. As such, larger states have larger samples.

High concentrations of chestnut were found in southern New England (Fig. 2), Pennsylvania, West Virginia-Virginia-Maryland (Fig. 3), and east Tennessee and western North Carolina (Fig. 4). Figures 2 to 4 also show the distribution of samples by tree-size class. It is notable but not surprising that the current extent and abundance suggested by this somewhat fragmented picture aligns with Braun's (1950) oak-chestnut forest region and mixed Mesophytic region to the west.

Site and Stand Characteristics

FIA site and stand data were used to characterize forest stands containing chestnut. The basic findings were similar to those of Braun (1950) who described the extent and abundance following the blight using existing reference sites and standing dead trees.

The contemporary chestnut population occurs across a range of slopes, but was rare on the steepest slopes (Table 2) and most common at elevations below 2000 feet. Chestnut was most prevalent on northeast-facing slopes, but was common on all aspects. About three-fourths of the chestnut occurred on mesic sites. It was also found on xeric sites. Chestnut was rare on very wet sites.

Forest resources in the eastern United States are primarily controlled by private forest landowners and stands containing chestnut are not an exception. Nearly 60 percent of the chestnut sample was on private land. The private owner group is a complex mix, from timber industry to small family owners. The National Forest System was the second most common owner with 25 percent of the total chestnut sample. The other public sample is incomplete because the existing sample excludes National Park Service land in the North Carolina portion of the Great Smoky Mountain Park and the Adirondack and Catskills State Parks in New York. New inventories will cover these lands in the future.

As was similarly found by Braun (1950), chestnut occurred most commonly in the oak-hickory forest-type group. The oak-hickory group covers a wide range of forest cover types, primarily of mixed-oak composition with varying proportions of other associates, such as yellow-poplar (*Liriodendron tulipifera* L.), hickory (*Carya* sp.), and other species depending on the region. More than 80 percent of the sample plots with chestnut were found in oak-dominated stands. Although found across the East, high concentrations of oak-dominated stands are very common in the Appalachian Mountains from central Pennsylvania to northern Alabama (McWilliams and others 2002).

In southern New England, chestnut occurs on glaciated soils with higher occurrence of red maple (*Acer rubrum* L.), sugar maple (*A. saccharum* Marsh.), beech (*Fagus grandifolia* Ehrh.), and white ash (*Fraxinus americana* L.) than regions to the south. The northern Ridge and Valley region of Pennsylvania is characterized by mixed-oak species with yellow-poplar and hickory being relatively rare. Yellow-poplar and hickory become more common in stands containing chestnut in the southern tier of Pennsylvania and the northern Blue Ridge areas of West Virginia and Virginia. Further south in the Southern Appalachians and Great Smoky Mountains, the number of associates increases. These differences in associates emphasize the high degree of species heterogeneity that exists throughout eastern North America.

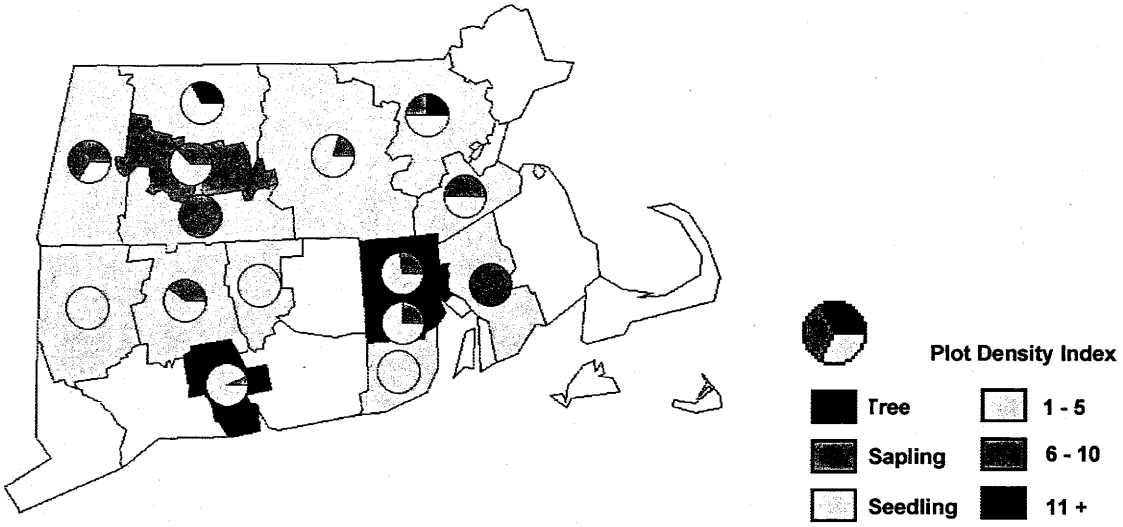

Figure 2. Distribution of live American chestnut showing chestnut plot density index and proportion of seedlings, saplings, and trees by county in Southern New England. [Note: Plot density index = number of plots with live chestnut/county area (sq. mi.) * 1000].

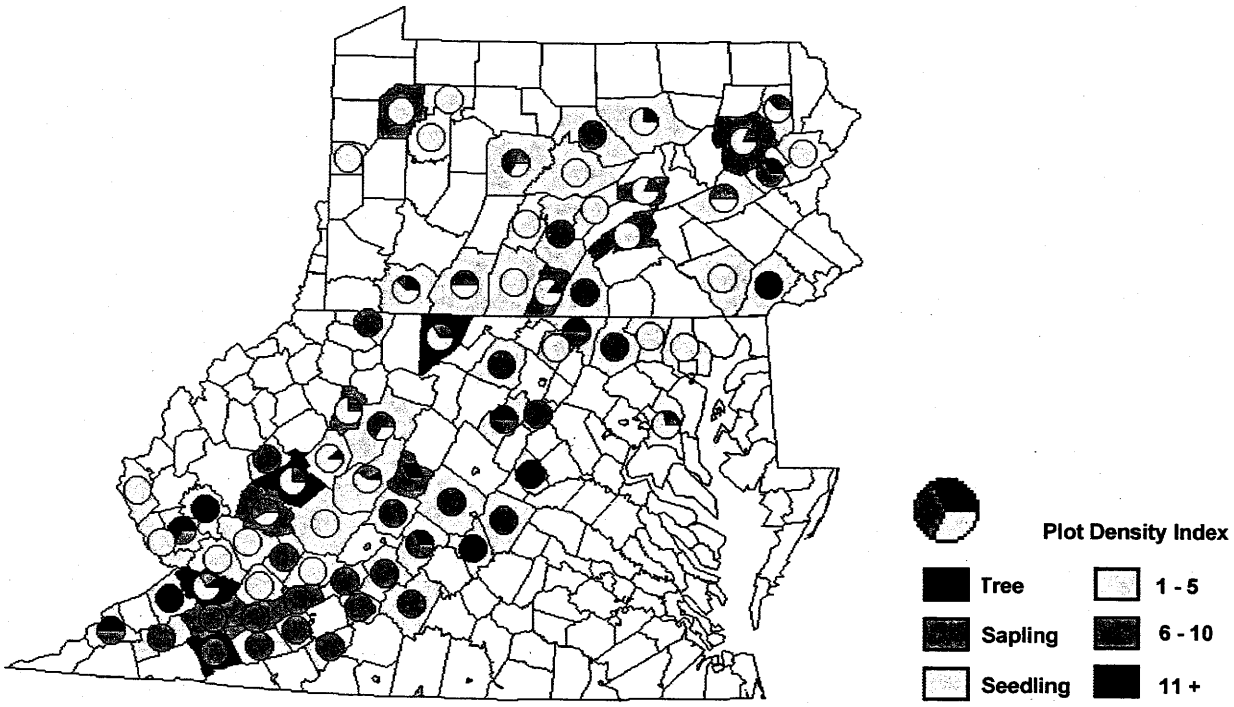

Figure 3. Distribution of live American chestnut showing chestnut plot density index and proportion of seedlings, saplings, and trees by county in Pennsylvania, Maryland, West Virginia, and Virginia. No seedling data available for Virginia. [Note: Plot density index = number of plots with live chestnut/county area (sq. mi.) * 1000].

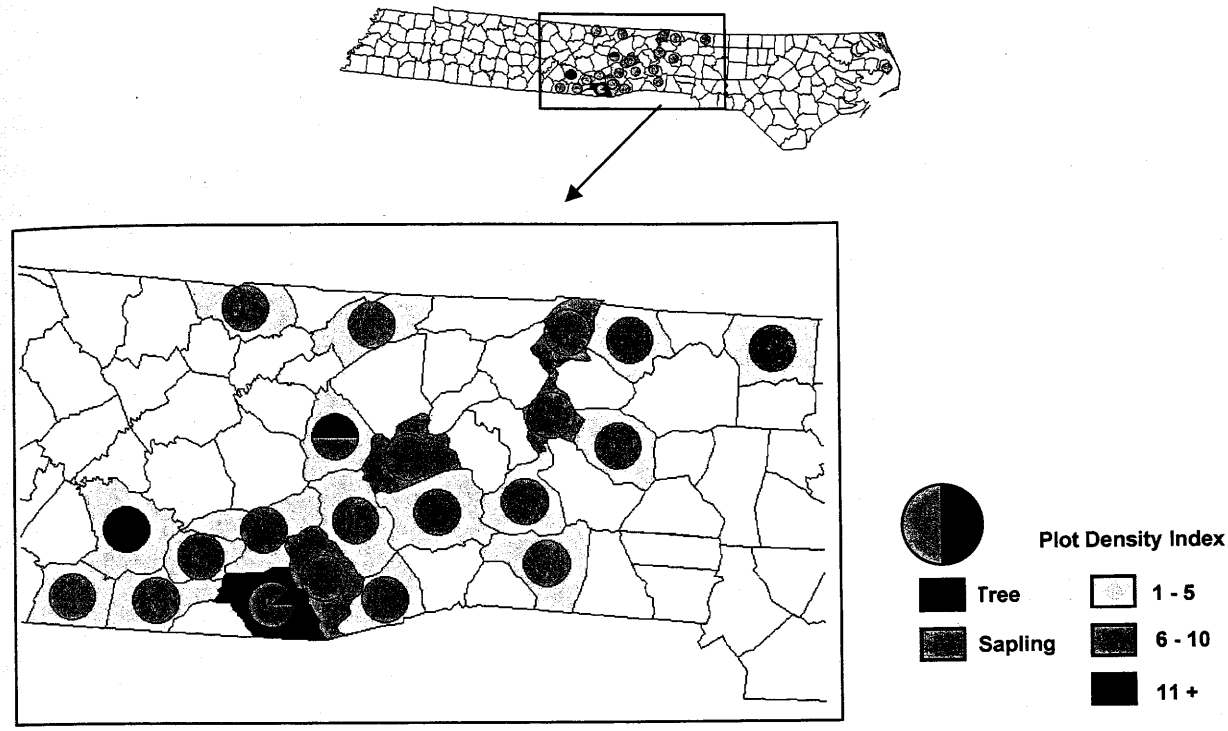

Figure 4. Distribution of live American chestnut showing chestnut plot density index and proportion of saplings and trees by county in east Tennessee and western North Carolina.
[Note: Plot density index = number of plots with live chestnut/county area (sq. mi.) * 1000].

The distribution of forest land containing chestnut by stand-size and stocking class was similar to the distribution for all forest land across its range. By stand-size class, the distribution was 60 percent sawtimber size, 28 percent mid-size, and 12 percent sapling-seedling size. Sawtimber stands are dominated by trees at least 9.0 and 11.0 inches in diameter for coniferous and deciduous species, respectively. Mid-size stands are dominated by trees at least 5.0-inches in diameter but smaller than sawtimber size. Sapling-seedling stands contain mostly trees less than 5.0 inches. Eighty-eight percent of the forest land with chestnut was in either medium (30-69 percent stocked) or fully (70-100 percent) stocked stands.

Large areas of eastern U.S. mountain and upland forests are evolving along similar compositional and structural trajectories. Stands containing chestnut are representative of these conditions. Dominant trends include forest land with increasing numbers of large-diameter trees, decreases in small to mid-range trees, mismatches between overstory and understory species composition, relatively few young sapling-seedling stands, and often, regeneration difficulties. Susceptibility to prominent pests, such as Asian long-horned beetle, elm-ash borer, and hemlock wooly adelgid threaten many of the canopy dominants that occur over significant areas. Future developments in these forests will affect chestnut's niche within natural and disturbed forest land.

Table 2. Site and stand characteristics expressed as a percent of plots with live American chestnut (at least 1.0-inches in diameter) sampled in the most recent FIA inventories conducted in the eastern United States.

--- Percent of Sample Plots ---

Slope		Elevation		Aspect	
0-5%	12	500'	8	NE	33
6-10%	10	1000'	38	SE	20
11-20%	19	1500'	17	SW	22
21-30%	14	2000'	14	NW	24
31-40%	15	2500'	11		
41-50%	14	3000'	6	**Moisture Class**	
51-60%	10	3500'	6		
61-70%	4	4000'	1	Hydric	- trace -
71-80%	2			Mesic	73
				Xeric	27

Ownership		Stand Size	
National Forest	25	Sapling-Seedling	12
Other Federal[1]	2	Mid-size	28
Other Public	14	Sawtimber	60
Private	59		

Forest Type Grouping		Relative Stocking	
White Pine-Hemlock	2	Over (>100%)	8
Spruce-Fir	-trace-	Full (70-100%)	55
Loblolly-Shortleaf	2	Medium (30-69%)	33
Oak-Pine	5	Low (< 30%)	3
Oak-Hickory	84		
Elm-Ash-Cottonwood	1		
Northern Hardwoods	6		
Aspen-Birch	1		

[1] The Other Federal ownership excludes forest land with chestnut in the Great Smoky Mountain National Park and the Adirondack and Catskills State Parks.

Numbers of Stems

Derivation of a population estimate for the total number of chestnut stems was precluded by some missing information for seedlings. However, an examination of the existing sample of sapling and tree-size stems suggests a decrease in sapling-size stems and an increase in tree-size stems over the two most recent inventory cycles. It is unfortunate that the seedling sample was incomplete because structural trends are not completely discernable. The critical question is what degree the seedling/sprout resource is changing. This resource represents recruitment of future chestnut stems. While the increase in tree-size stems is encouraging in terms of viability, the long-term sustainability of chestnut depends on recruitment of chestnut stems.

CONCLUSIONS

The FIA data provide a coarse description of the chestnut resource as it occurs in today's forests. The data indicate that the existing population of chestnut occupies the core of the oak-chestnut forest region described by Braun (1950) with relic communities found across its original range described by Little (1977). This is not surprising because chestnuts exist today mainly as sprouts (Paillet 1988). It is not possible to make a conclusive statement of the long-term sustainability of chestnut due to limitations of the current dataset. Future inventories will fill existing gaps and provide additional data needed for more thorough analysis of structural changes and trends in spatial extent. A significant benefit of the new national FIA system is improvement to the seedling and sapling measurement protocols. All seedlings are now tallied in a consistent manner. Sapling measurements now include total height, crown class, and condition. Remeasurement of these parameters will lead to improved datasets over the next 5 to 10 years.

Future extensions of research on chestnut using FIA data are readily apparent. The most obvious need is to provide more comprehensive data for analysis. Pending release of FIA results for Kentucky, North Carolina, and New York will fill some critical needs. The inclusion of seedling information in FIA's current national protocols will be particularly helpful. Once the gaps in data are filled, a more complete analysis of site occupancy could be conducted using geographic information systems (GIS). Modern GIS software is capable of analyzing hundreds of data layers that could help delineate characteristics associated with chestnut's occurrence. Improvements to FIA Phase 2 and new Phase 3 variables have resulted from nationalization of FIA protocols. For example, Phase 3 includes tree crowns, damage, down woody material, and others. These new variables offer the opportunity to develop improved indicators of chestnut condition and extent. The opportunities for improvement of our knowledge of chestnut at the landscape level are immense.

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