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measurement

Monitoring Nontimber Forest Products Using Forest Inventory Data: An Example with Slippery Elm Bark

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The USDA Forest Service Forest Inventory and Analysis (FIA) program collects data on a wealth of variables related to trees in forests. Some of these trees produce nontimber forest products (NTFPs) (e.g., fruit, bark, and sap) that are harvested for culinary, decorative, building, and medicinal purposes. At least 11 tree species inventoried by FIA are valued for their bark. For example, slippery elm (*Ulmus rubra* Muhl.) is included in FIA forest inventories, and the bark is used for its medicinal value. Despite widespread use of NTFPs, little quantitative information about abundance, distribution, and harvest is available to support sustainable management. Methods for using the FIA database to monitor and explain the situation regarding selected NTFPs are presented. The focus is on using FIA data to assess for (1) geographic distribution, (2) abundance, (3) applicable metrics (e.g., square feet of bark), and (4) change over time.

Keywords: nontimber forest products, Forest Inventory and Analysis, monitoring tools, bark measurement, automated

The forests of the United States provide an abundance of resources, products, recreational opportunities, and ecosystem services that benefit the people living in and near them, as well as around the world (Oswalt et al. 2012). Among these are nontimber forest products (NTFPs), plants and fungi harvested from forests used for diverse purposes. The ability to quantify the spatial and temporal distribution and abundance of NTFPs is important for monitoring the resource, assessing sustainable use, and answering broad-scale research questions.

The American Herbal Products Association solicits and aggregates data on quantities of medicinal plants that companies purchase as raw materials (Dentali and Zimmermann 2012). The amounts of NTFPs, including products coming from trees, harvested for commercial purposes alone are significant. For instance, more than 300,000 pounds of slippery elm bark were harvested annually (2006–2010) from US forests (Dentali and Zimmermann 2012). However, more data are needed to estimate total NTFP harvests, including noncommercial harvests. There is a lack of information on harvests from many state forests and little knowledge about the prevalence of illegal poaching (Frey and Chamberlain 2015). In light of this need, we explore ways to quantify various aspects of tree species that provide nontimber products using the FIA database.

NTFPs

NTFPs have been significant to the culture and commerce of the United States since before the country was founded. They are integral to subsistence economies, as well as to peoples' health, food security, and spiritual livelihoods (Emery and Pierce 2005, McClain et al. 2008). They expand the scope and scale of the forest products industry to include culinary, medicinal, decorative, landscaping, and nursery markets. More people harvest nontimber products from US forests for noncommercial benefits than they do for commercial benefits (Alexander et al. 2011). The commercial value of these forest products, however, is significant and has not been fully assessed in forest management planning (Alexander et al. 2011).

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NTFPs are collected for recreational, commercial, and subsistence purposes (Vaughan et al. 2013). Throughout the history of the United States, people of diverse backgrounds and cultures have derived their livelihood from NTFPs (Chamberlain et al. 1998, Emery 2002). However, lack of trust often inhibits collectors from sharing their knowledge with others (Vaughan et al. 2013). For example, Native Americans have special knowledge of NTFPs that has been passed through generations. Combining traditional ecological knowledge with science-based knowledge is providing valuable insights into ways to improve management for these products (Emery et al. 2014, Hummel and Lake 2015).

NTFPs originate from fungi and plants, including forest mosses, lichens, herbs, shrubs, vines, and understory and overstory trees. A general perception is that NTFPs come from plants other than trees. There are, however, many NTFPs that originate from trees and that are included in the Forest Inventory and Analysis (FIA) database. Iconic NTFPs from trees include the sap extracted from sugar maple (*Acer saccharum* Marsh.), the bark of paper birch (*Betula papyrifera* Marsh.), and the fruit of black walnut (*Juglans nigra* L.). In addition, Christmas ornamentals from the boughs of species such as noble fir (*Abies procera* Rehder.) are an important part of the floral and decorative NTFP segment (Blatner et al. 2009). Current understanding about these forest trees as producing NTFPs is lacking, and important insights into the dynamics of NTFPs from trees may be gleaned from knowledge sources such as FIA databases.

FIA

The FIA program of the US Department of Agriculture (USDA) Forest Service is the primary source of information on the status and trends of the nation's forest resources (Reams et al. 1999). By sampling all of the nation's forested lands over a periodic cycle, FIA provides the most comprehensive field inventory conducted today (Bechtold and Patterson 2005). Since NTFPs are an important subset of these renewable resources, efforts to improve information about these forest products by using and enhancing FIA is warranted.

FIA's spatially and temporally comprehensive sampling approach is appropriate for monitoring tree products in forests. Generally, within each subplot, trees are identified by species and status (living or dead) and measured for height, diameter, damage, and cause of death (USDA Forest Service 2014). These measurements can be used to monitor the status of NTFPs that come from tree species. By the use of expansion factors that rely on trees per acre and number of acres of a forest condition within a plot, tree measurements at the plot level allow for number and volume estimates that can be aggregated to any collection of plots, such as counties, FIA units, substate regions, states, and groups of states (Bechtold and Patterson 2005).

Measurement of understory plants that produce NTFPs is much less comprehensive. Whereas the sampling protocol and FIA data structure include provision for percent canopy cover measurement of understory plants, these measurements are available only for states from the Rockies west, including Alaska, Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming.

Background

Several studies have made use of FIA data to monitor and assess the status of selected NTFPs. Products that have been examined using FIA data include bark from paper birch (Emery et al. 2014), pine nuts from pinyon pines (*Pinus edulis* Engelm., *Pinus monophylla* Torr. and Frem., and *Pinus monophylla* var. *fallax* Torr.) (Shaw et al. 2005) and maple syrup from sugar maple (Farrell 2012).

These studies support the use of FIA data to document the spatial distribution and dynamics of NTFPs from trees. For example, the ability to detect the trend and magnitude of low levels of change caused by drought, insects, and disease on pinyon mortality has been attributed to FIA's annual inventory sampling design with yearly panels free of geographic bias (Shaw et al. 2005). Combining FIA data on the dbh of maple trees and the distance of each plot to the nearest road, Farrell (2012) was able to estimate the regional production potential of sugar maple stands. Supplementing FIA data with additional knowledge can improve resource assessments and the ability to manage for paper birch bark (Emery et al. 2014). Because paper birch bark is used to make various items, the number and measurements of trees that meet minimum size requirements are needed. Emery et al. (2014) estimated total bark surface area for trees with at least a 5-in. dbh as well as for trees with at least an 11-in. dbh, which are more suitable for making items such as canoes. Changes over time in these resources can be quantified through analysis of data from remeasured plots.

The examples here illustrate the usefulness of leveraging FIA data to quantify abundance, spatial distribution, and change over time of NTFPs derived from tree species. Despite the accessibility of FIA data, summary analyses of this type have been lacking for many NTFP species. The following demonstrates approaches and methods for analyzing any tree species in the database with specific examples of calculations and results.

Methods

Using FIA databases and expert knowledge of NTFPs, an initial 19 tree species (Table 1) that are harvested for their non-

Management and Policy Implications

The commercial value of nontimber forest products (NTFPs) is significant and has not been fully assessed (Alexander et al. 2011). Development of awareness that some NTFPs originate from trees and are already included in the Forest Inventory and Analysis (FIA) program is critical to incorporating these products into forest monitoring policy. For example, slippery elm and at least 10 other tree species are harvested for their bark, which is typically not considered in management decisions. Use of readily available data from FIA and graphical and tabular analytics that can be replicated across various species and geographic areas can provide valuable insights to both managers and policy makers by spatially monitoring availability and sustainable use of these resources for this valuable NTFP. Use of FIA to improve monitoring of understory species harvested for nontimber products is more limited. Protocols have been developed to collect data on some understory vegetation, but they are limited in scope and use. Policy directives to enhance these measurements would help quantify understory vegetation species and allow for better monitoring of NTFPs. An automated process for analyzing and summarizing FIA data on NTFPs in common trade units is a desirable and feasible goal. Research funds to support these efforts could markedly improve monitoring of NTFPs.

Table 1. Sample of trees found in FIA databases that are harvested for NTFPs.

Location	FIA code	Common name	Scientific name	Usage
East/West	375	Paper birch	*Betula papyrifera*	Bark, decorative
East	129	White pine	*Pinus strobus*	Bark, medicine
East	601	Butternut	*Juglans cinerea*	Bark, medicine
East	611	Sweetgum	*Liguidambar styraciflua*	Bark, medicine
East	762	Black cherry	*Prunus serotina*	Bark, medicine
East	802	White oak	*Quercus alba*	Bark, medicine
East	931	Sassafras	*Sassafras albidum*	Bark, medicine
East/West	927	White willow	*Salix alba*	Bark, medicine
West	231	Pacific yew	*Taxus brevifolia*	Bark, medicine
East	975	Slippery elm	*Ulmus rubra*	Bark, medicine
East	621	Yellow-poplar	*Liriodendron tulipifera*	Bark, siding
East	367	Pawpaw	*Asimina triloba*	Fruit, edible
East	521	Common persimmon	*Diospyros virginiana*	Fruit, edible
East/West	602	Black walnut	*Juglans nigra*	Medicine
East/West	561	Gingko	*Gingko biloba*	Leaves, medicine
East	318	Sugar maple	*Acer saccharum*	Sap, edible
West	106	Two-needle pinyon	*Pinus edulis*	Seeds, edible
West	133	Singleleaf pinyon	*Pinus monophylla*	Seeds, edible
West	143	Arizona pinyon pine	*Pinus monophylla* var. *fallax*	Seeds, edible

Table 2. Summary metrics for NTFP tree species computed from FIA data.

Type of measurement	Summary metrics
Abundance	Number of trees
	Number of trees by diameter class
	Surface area
	Surface area by diameter class
Spatial distribution	Plot locations
	Number of trees by FIA unit
	Surface area by FIA unit
Change over time	Number of trees and percent change (2007 to 2012)
	Number of trees by diameter class and percentage
	Change (2007 and 2012)
	Surface area and percent change (2007 to 2012)
	Net growth, mortality, removals, gross growth, and volume (2007 and 2012)
Change by location	Percent change in number of trees by FIA unit
	Percent change in surface area by FIA unit
	Mortality by FIA unit
	Net growth, removals, and mortality by state

timber values were identified by USDA Forest Service personnel and categorized according to use. The majority of the species in this list are valued for their bark and used in herbal medicines, and a large number are enjoyed for their culinary benefits. This list of species is not comprehensive and can be expanded to any pertinent NTFP tree species.

All of these tree species were analyzed across their entire range using 2007 and 2012/2013 population evaluation groups. On occasion, a population evaluation group for the desired year was not available for a given state. Most often this was because measurement of that year's panel extended well into the next year. In these unusual cases, the next closest available year was used.

Summary metrics were defined for each species to assess abundance, map spatial distribution, and estimate change over time (Table 2). Abundance was quantified and mapped by total number of trees, number of trees by diameter class, plot locations with live trees, and number of trees by FIA unit. Changes in abundance were presented by examining differences in periodic remeasurements and percent change in number of trees overall, in the number of trees by diameter class and by FIA unit, net growth, removals, and mortality (where available), and mortality by FIA unit (where available).

Summary metrics were most easily obtained using EVALIDator, an online reporting tool that can be used to summarize FIA data (Miles 2014). EVALIDator cannot be used to report plot-level details but can limit results to a given species. For example, to obtain number of trees by diameter class for each FIA unit for a certain species, the user makes a series of selections from EVALIDator. The user first specifies the attribute to be summarized (number of all live trees on forestland) and then selects the appropriate population evaluation group(s), followed by a row, column, and/or page factor on which to summarize (such as FIA unit and diameter class), and finally the user may limit the query to a certain tree species or in some other way if desired (such as dbh at least 5 in.).

Other queries, including approximate plot locations (LAT/LON) done at the plot level, must rely on database management tools such as Microsoft Access. Plot coordinates are approximated to within 1.0 mile of the exact plot location and up to 20% of the private plot coordinates are swapped with another similar private plot within the same county (O'Connell et al. 2015). Entire state Access databases can be downloaded from the FIA website.[1] Access databases contain built-in queries for state-level estimates by population evaluation group. Experienced users can alter these built-in queries to summarize estimates at the unit, county, or plot level. For example, a query for number of all live trees on forestland at the state level could be altered to obtain number of trees on a plot by changing the query to include a plot identifier. By adding fields for population evaluation group, tree diameter, or species code, the query could be altered to limit results to certain measurement years and trees with at least a 5-in. dbh and of a certain species. Furthermore, fields for latitude and longitude could be added to a query to obtain the approximate geographic coordinates of each plot in the result.

FIA data from multiple states are required when one queries for results across an entire species range. In these cases, it may be easier to use other database management software such as Microsoft SQL Server. The individual tables representing the entire nation needed to perform the desired queries can also be downloaded from the FIA website. Some of these nationwide tables are too large for Access to handle, and performing the same query in Access repetitively for each state can be cumbersome. Thus, maps of point locations of plots containing selected species were created using SQL Server. Writing scripts of code in SQL or another language is also useful for automating analyses of new FIA data in successive years.

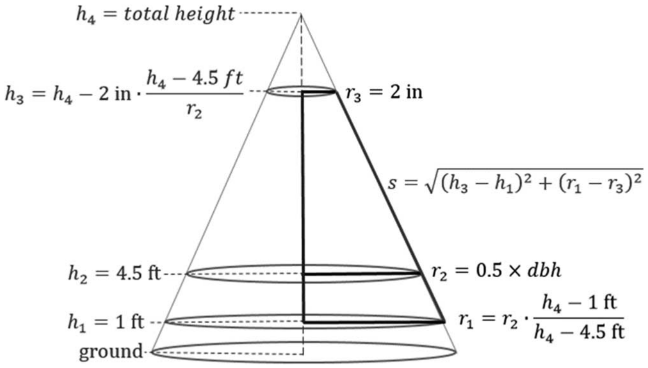

Figure 1. Geometric representation of the surface area of a truncated cone representing the bole of a tree.

Table 3. Parameters (SE) and *df* for linear regression lines modeling the relationship between $\sqrt{\text{dbh}}$ and $\sqrt{\text{SA}}$ of bark for boles of trees at least 5 in. dbh by species, using 2012 population evaluation groups.

Species	FIA code	*a*	*b*	*df*
Paper birch	375	−6.541 (0.025)	4.661 (0.009)	25,062
White pine	129	−7.835 (0.021)	5.039 (0.006)	30,749
Butternut	601	−6.440 (0.223)	4.553 (0.071)	323
Sweetgum	611	−8.223 (0.014)	5.402 (0.005)	54,711
Black cherry	762	−7.474 (0.210)	5.020 (0.007)	30,540
White oak	802	−7.292 (0.017)	4.974 (0.005)	52,250
Sassafras	931	−6.971 (0.051)	4.781 (0.018)	6,800
White willow	927	−4.118 (0.715)	3.523 (0.220)	13
Pacific yew	231	−2.906 (0.395)	2.664 (0.156)	25
Slippery elm	975	−7.018 (0.046)	4.820 (0.016)	6,102
Yellow-poplar	621	−8.270 (0.018)	5.504 (0.005)	36,241

Calculating Surface Area

For trees from which bark is harvested, the bole surface area is of particular interest for estimating product quantity. Eleven tree species that are valued for their bark were identified (Table 1). FIA defines the bole of a tree as the portion from a 1-ft stump to a 4-in. diameter top (O'Connell et al. 2015). Accepting this definition, a truncated cone can be used as an appropriate representation of the bole. Equation 1 is the standard formula for calculating the surface area (*SA*) of a truncated cone in square feet

$$SA = \pi \times (r_1/12 + r_3/12) \times s \quad (1)$$

In Equation 1, r_3 denotes the radius at the top of the bole (2 in. or one half of the 4-in. diameter), r_1 represents the radius in inches at a 1-ft stump, and s symbolizes the slant height in feet (shortest distance between edges of the top and bottom of the bole). The bole of a tree with a specified dbh and total height can be represented by Figure 1. In this diagram, r_1 and r_3 are derived from dbh (2 times r_2), total height (h_4), and similar triangles. This results in Equation 2 for surface area

$$SA = \pi \times \left(dbh/24 \cdot \frac{h_4 - 1}{h_4 - 4.5} + 1/6 \right) \times \sqrt{\left[\left(h_4 - 1/6 \cdot \frac{h_4 - 4.5}{r_2/12} \right) - 1 \right]^2 + \left[\left(dbh/24 \cdot \frac{h_4 - 1}{h_4 - 4.5} \right) - 1/6 \right]^2} \quad (2)$$

where *SA* is the surface area in square feet, *dbh* is the dbh in inches, and h_4 is the total height (actual length plus any missing broken piece) (O'Connell et al. 2015). Records for live trees at least 5 in. dbh on forestland can be obtained from the FIA database for the desired population evaluation group. Total surface area for the measurement unit can be estimated by multiplying the surface area for each tree in the sample as calculated by Equation 2 by the number of trees per acre for the plot/condition containing the tree and the number of acres represented by the plot/condition and then summing over all plot/conditions (O'Connell et al. 2015).

With FIA data on thousands of trees sampled across their range for most species, regression equations provide a good means for estimating bark SA directly from dbh. This eliminates the need for total height measurements and simplifies the process for estimating total SA for future calculations. We calculated SA using Equation 2 and dbh and total height from each live tree of a selected species at least 5 in. dbh before performing the regression. Table 3 provides the parameters of linear equations for each of the 11 bark species resulting from regressing $\sqrt{SA}$ on $\sqrt{dbh}$. These square root transformations help to maintain the ordinary least squares regression assumption of equal variance across the range of the explanatory variable, providing for better estimates.

Establishing a relationship between SA and dbh allows for surface area estimates requiring only dbh of trees in the sample. If FIA data are being used, the process for estimating total SA for a species across a region is to perform an EVALIDator query for number of trees by diameter class in that region. This eliminates the need for the manager to query the database to retrieve dbh and total height for each tree in the appropriate sample and then expand the estimate on the appropriate plots to all forest area in the region of interest. EVALIDator ensures that the correct trees are used in the sample for estimating the number of trees by diameter class in the desired region. By substituting the midpoint of each diameter class and the appropriate parameters from Table 3 into the following formula,

$$SA = (a + b\sqrt{dbh})^2 \quad (3)$$

SA within each class can be estimated by multiplying by the number of trees in each class obtained from EVALIDator. Summing the results of each class yields the overall total surface area.

Results: Slippery Elm as an Example

The approach described was used to obtain estimates for all tree species in the study, and results from slippery elm are presented here as an example. The inner bark of slippery elm trees is valued as one of the most common herbal remedies and as an ingredient in throat lozenges and nutritional supplements and for other medicinal purposes (Pengelly and Bennett 2011). Because of the medicinal value of its bark, slippery elm was chosen as the first tree species for analysis using these methods.

The native range of slippery elm is most of the eastern United States, and the distribution of FIA plots containing slippery elm closely matches this range (US Geological

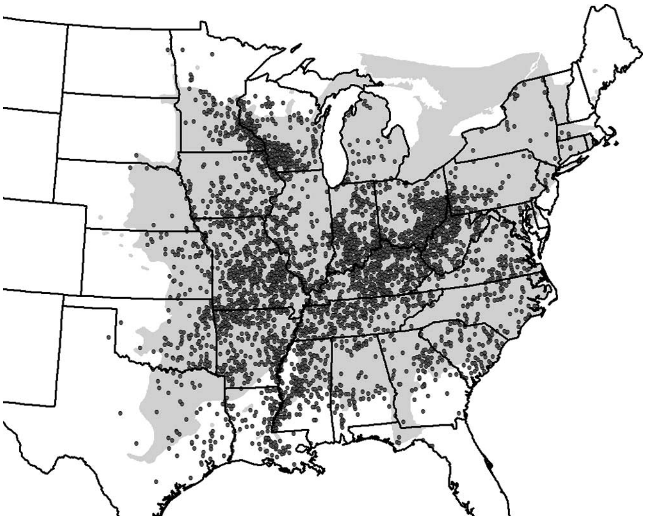

Figure 2. Locations of FIA plots from the 2012 population evaluation group containing slippery elm trees of 5 in. dbh or larger within species range map.

Table 4. Average annual net growth, mortality, removals, and gross growth, along with net volume of live slippery elm trees 5 in. dbh or larger on forestland estimated from recent (2013) and previous inventories.

Parameter	2007	2013
	. . . .(million cu ft)	. . . .
Average annual net growth*	13 (−1.6 to 28)	0.59 (−9.1 to 10.3)
Average annual mortality	57 (42 to 72)	69 (60 to 78)
Average annual removals	9.6 (5.5 to 14)	16 (11 to 20)
Average annual gross growth	70 (40 to 100)	70 (51 to 88)
Net volume of live trees	1,890 (1,776 to 2,005)	1,699 (1,600 to 1,798)

Data are averages (95% confidence interval). Previous inventory values are approximately 5-year state prior inventories (e.g., state inventory closest to 2007). Results do not include West Texas.

* Negative net growth values are usually due to mortality but can also occur on live trees that have a net loss in volume because of damage, rot, broken top, or other causes.

Survey 1999) (Figure 2). An EVALIDator query for the 2013 population evaluation groups of states across its range estimates 1,011 ± 55 million slippery elm trees, of which 20.5% or 207 million (±9 million) were at least 5 in. dbh.

Annual net growth, removals, mortality, and net volume were estimated for 2007 and 2013 population evaluation groups, and 95% confidence bounds were provided (Table 4). Estimated average annual net growth decreased from 13 to 0.59 million cu ft with 95% confidence intervals containing negative net growth (mortality exceeds growth) for both sample years. Estimated average annual mortality increased from 57 to 69 million ft^3. Estimated average annual removals increased from 9.6 million cu ft in 2007 to 16 million cu ft in 2013, approximately 71%.

The low and declining net growth of slippery elm corresponds to a decreasing number of trees. The number of trees at least 5-in. dbh declined from an estimated 231 ± 10 million in 2007 to 207 ± 9 million trees in 2013. These 95% confidence intervals do not overlap, which suggests a statistically significant difference and represents an approximate 10.4% decrease in number of trees at least 5-in. dbh.

Figure 3 illustrates comparisons in number of trees and mortality by FIA unit. The map on the top shows the number of slippery elm in 2012 by FIA unit, the middle map shows percent change in number of slippery elm from 2007 to 2012, and the map on the bottom shows average yearly slippery elm mortality from 2007 to 2012 in millions of cubic feet. These maps can help managers and scientists identify areas with higher mortality and greater percent change that may warrant further attention as opposed to areas that have higher mortality merely due to an abundance of slippery elm. Units with a high number of trees, large percent decreases in number of trees, and high mortality may merit closer investigation and higher priority for management or interventions.

Figure 4 illustrates the distribution of slippery elm bole surface area by diameter class, calculated by substituting the midpoint of each diameter class and the slippery elm parameters from Table 3 into Equation 3 and then multiplying by diameter class frequencies from an EVALIDator query for number of slippery elm by diameter class (right-hand bars). Clearly, a majority of surface area is in small diameter classes. Summing across all diameter classes, we estimate the total area of slippery elm bark in 2012 at 10.97 billion ft^2. Diameter class estimates using total height and dbh for each tree in the database are shown in the left-hand bars for comparison purposes.

Discussion

Far more slippery elm volume is being harvested than is being grown (Table 4), indicating high harvest pressure. More cause for concern is the fact that mortality is seriously outpacing removals (Table 4), resulting in a statistically significant drop in the number of live trees. Therefore, further information related to possible causation was extracted from the FIA database. Comparing the mortality rate (mortality as a percentage of total volume) of slippery elm with the three most common tree species associated with slippery elm (i.e., most commonly co-occurring on plots) shows that the mortality rates for slippery elm and American elm (*Ulmus americana* L.) are greater than 4% (4.05 and 4.64%, respectively) on plots containing at least one slippery elm, much higher than for sugar maple and sweetgum (0.69 and 0.86%, respectively). Most likely, this is due to the susceptibility of both species to Dutch elm disease (*Ophiostoma ulmi* [Buisman] Nannf. and *Ophiostoma novo-ulmi* Brasier).

However, overharvesting or improper harvesting of slippery elm bark is a possible explanation for the increased mortality. Table 5 shows the causes of mortality for slippery elm and American elm on plots with at least one slippery elm tree recorded in the FIA database. The percentage of deaths due to disease was lower for slippery elm than it was for American elm, whereas the percentage of deaths in the "unknown, not sure, other" category was greater. This category "includes death from human activity not related to silvicultural or land-clearing activity." This could involve improper removal of

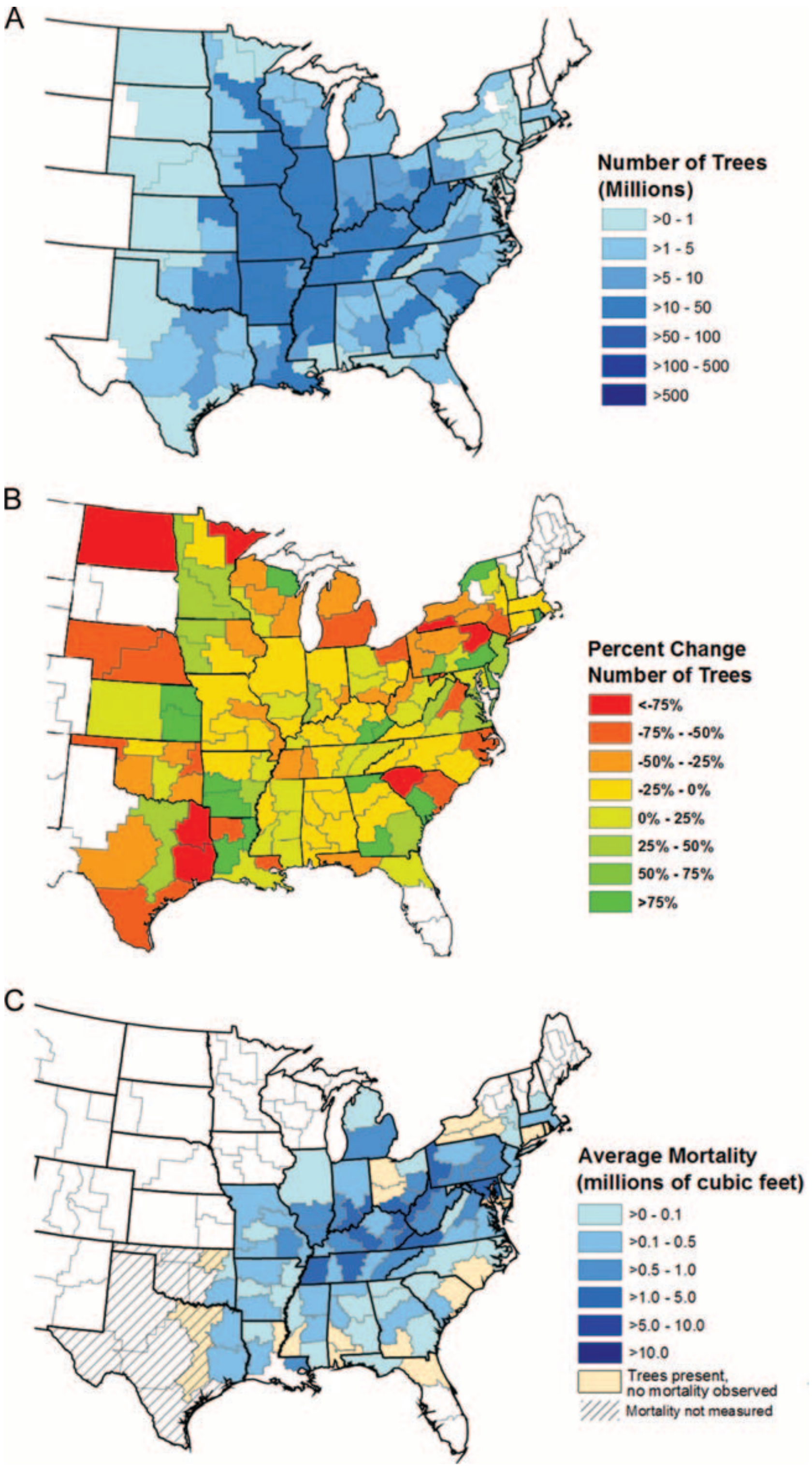

Figure 3. Top: number of slippery elm in 2012. Middle: percent change in number of slippery elm from 2007 to 2012. Bottom: Average yearly slippery elm mortality from 2007 to 2012 by FIA unit.

bark and provides a basis for additional investigation.

Broad analyses as described above and summarized in Table 2 have been completed for all 19 tree species in Table 1 and show that FIA data can be used to monitor NTFPs from many different tree species. Rather than include all of these results here, total net growth, removals, mortality, 2007 net volume, and 2013 net volume on forestland for trees of at least 5 in. dbh with their associated sampling error percent from EVALIDator are summarized in Table 6. Calculating the growth-removal ratio, mortality as a percentage of net volume, and percent decrease in volume as a means to monitor status of a resource may be appropriate for species with low percent standard errors for the above estimates. For example, the growth/removal ratios (0.04 versus 1.99), mortality as a percentage of volume (4.06 versus 0.72), and percent change in volume (−11.24 versus 3.91%) of slippery elm (former) versus sugar maple (latter) can be compared. Slippery elm's lower growth removal ratio, higher mortality as a percentage of volume, and negative percent change in volume indicate that it is of more concern than sugar maple. However, the low growth/removal ratio for slippery elm should be treated with caution due to the high sampling error percentage for net growth.

Surface area models other than the simple truncated cone used here (Figure 1 and Equation 2), such as the two stacked conical frustum model used by Emery et al. (2014), are common. In their study, stump diameter/dbh ratios and taper estimates were available. However, these estimates are not contained in the FIA database and are not readily available for many species. For the purposes of estimating change, consistent use of any good surface area model is appropriate.

Addition of stump diameter measurements (2 times r_1 in Figure 1) for each tree in the FIA database along with additional research to provide taper estimates for species valued for their bark would enhance the database to allow for alternative surface area calculations. In fact, including measurements for heights at 4-in., tops of boles (h_3 in Figure 1), or height and diameter at some other height of the upper portion of the bole would facilitate research on taper. This would allow for models of the bole that more closely represent the shapes of individual species and may result in better surface area estimates for bark species.

Conclusion

The FIA database is a useful information source for monitoring tree species that are valued for NTFPs. The FIA sampling design provides good estimates over large areas and, in general, regularly remeasures plots. The database is improving with more comprehensive net growth, mortality, and removal estimates as western states complete their first cycles of annual inventory.

FIA data alone provide a good start for

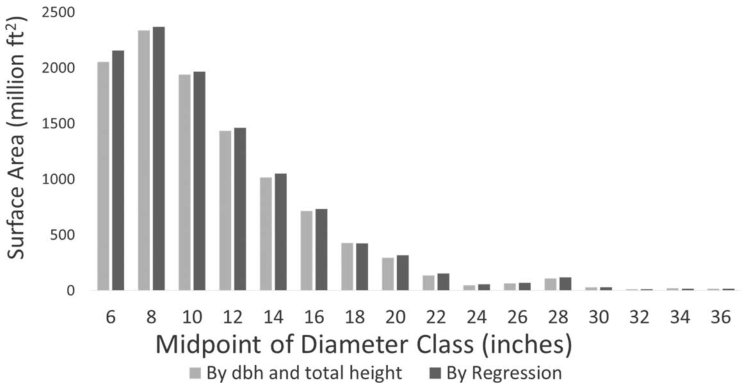

Figure 4. Estimated total surface area (million ft²) of live slippery elm trees of 5 in. dbh or greater on forestland by diameter midpoint class from recent (2012) inventories.

Table 5. Causes of mortality for slippery elm and for American elm colocated on plots.

Cause of mortality	American elm		Slippery elm	
	Deaths	% deaths	Deaths	% deaths
Insect	53	1.01	19	1.16
Disease	2,358	44.86	482	29.44
Fire	8	0.15	5	0.31
Animal	41	0.78	6	0.37
Weather	242	4.60	106	6.48
Vegetation	416	7.91	267	16.31
Unknown/not sure/other*	1,286	24.47	478	29.20
Silvicultural or landclearing activity	852	16.21	274	16.74
Total	5,256	100	1,637	100

* Includes death from human activity not related to silvicultural or land-clearing activity.

estimating quantities of bark products for tree species by calculating surface area. However, different bark components, such as inner bark versus outer bark, are valued, depending on species. Furthermore, bark products are rarely traded in square feet. Additional research is needed to convert estimates made from tree measurements (e.g., bark surface area) to quantities relevant for trading NTFPs (e.g., dry weight of inner bark).

Our sample analysis of slippery elm along with completed analyses of the other species in Table 1 and examples of other studies involving NTFPs and FIA shows that FIA data can be augmented for various NTFP species and types of products, including syrup, nuts, and bark (Shaw et al. 2005, Farrell 2012, Emery et al. 2014). Although procedures for estimating quantities of some NTFPs have not incorporated FIA, procedures such as the one used by Blatner et al. (2005) to estimate noble fir bough weight could be adapted to incorporate FIA or used if additional measurements are included with FIA.

Access to reliable spatial and temporal data is vital to most effectively manage for NTFPs. FIA data can be used as an important component of a process that monitors NTFPs and manages forests in a manner inclusive of them. Tree data of this type and amount can alert the professional forester

Table 6. Average annual 2013 net growth, mortality, and removals and 2007 and 2013 net volume (sampling error percentage) of trees 5 in. dbh or larger on forestland.

Common name	Average annual net growth of live trees ≥5 in. dbh	Average annual mortality of trees ≥5 in. dbh	Average annual removals of live trees ≥5 in. dbh	Net volume of live trees ≥5 in. dbh 2007	Net volume of live trees ≥5 in. dbh 2013
	(million cu ft)				
Paper birch	*	*	*	6,047 (1.96)	5,246 (2.02)
White pine	637 (2.98)	141 (6.72)	231 (8.34)	18,853 (2.08)	20,653 (2.07)
Butternut	−3.65 (68.9)	10.3 (22.9)	0.56 (42.6)	183 (9.13)	132 (10.5)
Sweetgum	739 (2.95)	198 (4.60)	466 (4.22)	23,316 (1.37)	22,796 (1.58)
Black cherry	422 (3.32)	123 (4.42)	150 (7.28)	12,483 (1.89)	13,549 (1.82)
White oak	779 (2.21)	209 (4.57)	429 (4.94)	34,445 (1.09)	35,007 (1.16)
Sassafras	20.6 (17.6)	39.4 (6.96)	18.2 (14.1)	1,596 (3.50)	1,593 (3.64)
White willow	0.132 (186)	0.281 (63.1)	None†	25.6 (49.2)	26.4 (59.8)
Pacific yew	*	*	*	40.0 (14.7)	40.9 (12.6)
Slippery elm	0.59 (837)	68.9 (6.57)	15.7 (15.1)	1,889 (3.09)	1,699 (3.29)
Yellow-poplar	1,165 (2.03)	183 (5.55)	470 (5.39)	31,937 (1.56)	34,786 (1.59)
Pawpaw	0.36 (40.5)	0.082 (47.1)	0.20 (65.2)	3.10 (31.0)	2.77 (24.2)
Common Persimmon	2.57 (66.1)	14.6 (10.5)	5.21 (4.01)	540 (4.01)	500 (4.70)
Black walnut	169 (3.95)	22.9 (10.5)	48.9 (15.0)	3,732 (2.80)	4,187 (2.57)
Gingko	0.004 (90.0)	None†	None†	1.37 (72.5)	0.782 (99.4)
Sugar maple	640 (2.63)	226 (4.94)	321 (5.56)	30,366 (1.21)	31,601 (1.25)
Two-needle pinyon	−22.5 (‡)	119 (‡)	*	7,423 (2.36)	7,473 (2.12)
Singleleaf pinyon	*	*	*	4,167 (5.07)	3,853 (2.86)
Arizona pinyon pine	−824 (86.9)	3.55 (19.9)	*	146 (13.1)	195 (10.3)

Results do not include West Texas.
* Not measured for significant portion of range.
† None observed in sample.
‡ Total sampling error percent for multiple states in the Interior West not available with EVALIDator.

when a species is in jeopardy. Expert knowledge can refine measurements and techniques specific to each species. The use of FIA data for analysis of NTFPs can be replicated across species and wide geographic areas in an automated manner. However, use of FIA to understand understory species is more limited. Subplot data on vegetation are currently constrained to western states and give percent canopy cover data on subplots containing the resource. Expansion to all states and enhancement of vegetation measurements could help quantify NTFP products derived from understory species.

Endnote

1. For more information, see www.fia.fs.fed.us/tools-data/.

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